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A SERIES OF TEXTBOOKS FOR PERSONS ENGAGED IN THE ENGINEERING PROFESSIONS AND TRADES OR FOR THOSE WHO DESIRE INFORMATION CONCERNING THEM. FULLY ILLUSTRATED AND CONTAINING NUMEROUS PRACTICAL EXAMPLES AND THEIR SOLUTIONS

PLUMBING AND GAS-FITTING
HEATING AND VENTILATION OF BUILDINGS
PAINTING AND DECORATING
ESTIMATING AND CALCULATING QUANTITIES

SCRANTON:
INTERNATIONAL TEXTBOOK COMPANY

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PREFACE

The International Library of Technology is the outgrowth of a large and increasing demand that has arisen for the Reference Libraries of the International Correspondence Schools on the part of those who are not students of the Schools. As the volumes composing this Library are all printed from the same plates used in printing the Reference Libraries above mentioned, a few words are necessary regarding the scope and purpose of the instruction imparted to the students of—and the class of students taught by—these Schools, in order to afford a clear understanding of their salient and unique features.

The only requirement for admission to any of the courses offered by the International Correspondence Schools is that the applicant shall be able to read the English language and to write it sufficiently well to make his written answers to the questions asked him intelligible. Each course is complete in itself, and no textbooks are required other than those prepared by the Schools for the particular course selected. The students themselves are from every class, trade, and profession and from every country; they are, almost without exception, busily engaged in some vocation, and can spare but little time for study, and that usually outside of their regular working hours. The information desired is such as can be immediately applied in practice, so that the student may be enabled to exchange his present vocation for a more congenial one or to rise to a higher level in the one he now pursues. Furthermore, he

wishes to obtain a good working knowledge of the subjects treated in the shortest time and in the most direct manner possible.

In meeting these requirements, we have produced a set of books that in many respects, and particularly in the general plan followed, are absolutely unique. In the majority of subjects treated the knowledge of mathematics required is limited to the simplest principles of arithmetic and mensuration, and in no case is any greater knowledge of mathematics needed than the simplest elementary principles of algebra, geometry, and trigonometry, with a thorough, practical acquaintance with the use of the logarithmic table. To effect this result, derivations of rules and formulas are omitted, but thorough and complete instructions are given regarding how, when, and under what circumstances any particular rule, formula, or process should be applied; and whenever possible one or more examples, such as would be likely to arise in actual practice —together with their solutions—are given to illustrate and explain its application.

In preparing these textbooks, it has been our constant endeavor to view the matter from the student's standpoint, and to try and anticipate everything that would cause him trouble. The utmost pains have been taken to avoid and correct any and all ambiguous expressions—both those due to faulty rhetoric and those due to insufficiency of statement or explanation. As the best way to make a statement, explanation, or description clear is to give a picture or a diagram in connection with it, illustrations have been used almost without limit. The illustrations have in all cases been adapted to the requirements of the text, and projections and sections or outline, partially shaded, or full-shaded perspectives have been used, according to which will best produce the desired results. Half-tones have been used rather sparingly, except in those cases where the general effect is desired rather than the actual details.

It is obvious that books prepared along the lines mentioned must not only be clear and concise beyond anything

heretofore attempted, but they must also possess unequaled value for reference purposes. They not only give the maximum of information in a minimum space, but this information is so ingeniously arranged and correlated, and the indexes are so full and complete, that it can at once be made available to the reader. The numerous examples and explanatory remarks, together with the absence of long demonstrations and abstruse mathematical calculations, are of great assistance in helping one to select the proper formula, method, or process and in teaching him how and when it should be used.

This volume contains papers on the subjects of plumbing and gas-fitting, heating and ventilation of buildings, painting and decorating, and estimating and calculating quantities, and will be found of great service to the building contractor and quantity surveyor, as well as all other persons interested in the estimation and calculation of materials that go into a building. The paper on Plumbing and Gas-Fitting treats the subject from the plumber's standpoint with a view to making it perfectly practical to the architect, draftsman, or building superintendent. The paper on Heating and Ventilation of Buildings explains such theories and practices as find favor among the leading architects of the present day. The paper on Painting and Decorating treats on the durability, quality, and general excellence of work rather than artistic merit, the latter being treated in another volume.

The method of numbering the pages, cuts, articles, etc. is such that each subject or part, when the subject is divided into two or more parts, is complete in itself; hence, in order to make the index intelligible, it was necessary to give each subject or part a number. This number is placed at the top of each page, on the headline, opposite the page number; and to distinguish it from the page number it is preceded by the printer's section mark (§). Consequently, a reference such as § 37, page 26, will be readily found by looking along the inside edges of the headlines until § 37 is found, and then through § 37 until page 26 is found.

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CONTENTS.

PLUMBING AND GAS-FITTING.

PLUMBING.

INTRODUCTION.

1. The duty of a **plumber** is to provide dwellings and other buildings with systems of piping, the several objects of which are:

1. To supply and distribute water to convenient points.
2. To receive and conduct away all dirty and refuse water.
3. To conduct away and dispose of all filth, excreta, and other sewage matter, and to remove all noxious odors arising therefrom.

He also provides apparatus for heating water, and for pumping, storing, and measuring cold water, also lavatories and baths, laundry tubs and sinks, water closets and urinals, cesspools, drains, etc.

The comfort and healthfulness of dwellings, especially in towns and cities, depend in a great measure upon the adequacy and thoroughness of the plumbing. And, as the health of the inmates is seriously affected by defective drainage, it is necessary that the work of the plumber shall be thoroughly and conscientiously performed. The general public are profoundly ignorant of the importance of thorough drainage, and in many cases the plumber must protect people against the evil consequences of their own ignorance. In many communities laws have been made which greatly aid him in constructing drainage systems as they should be.

2. In all cases of new buildings, or repairs, or remodeling old buildings, the architect must furnish plans and specifications of the plumbing work, and the plumber is guided by them. Of course, in order to prevent conflict with the health authorities, the plumber must also be controlled to a certain extent by the plumbing ordinances of the city in which the work is to be done. It is well, therefore, that all architects should provide themselves with office copies of the rules and regulations which govern plumbers and plumbing, so that they may be enabled to design the plumbers' work in accordance therewith. A copy, in pamphlet form usually, can be easily obtained by application to the Health Department, the Building Department, or the Plumbing Inspector, as the case may be.

3. It is necessary that the architect should possess a little knowledge of the nature of the materials used in plumbing. He should also become familiar with the mode of performing the necessary operations upon them, both the shop work and the outside work; and he should acquire a clear comprehension of what is necessary to constitute an efficient and satisfactory system of water supply, a safe and reliable system of drainage, and a complete and convenient outfit of fixtures and domestic apparatus.

PLUMBING FIXTURES.

SINKS.

4. Sinks are of several varieties; viz., kitchen sinks, butlers' pantry sinks, and slop sinks.

They are made of wood, cast iron, steel, enameled iron, brown glazed earthenware, porcelain, soapstone, slate, etc.

All sinks should be provided with a strainer and waste pipe. The waste pipe should be trapped if it extends to a drain pipe or cesspool; or, even if it is open to the air at the end, it should be trapped to prevent the wind from blowing foul odors back into the house.

5. Kitchen sinks should be placed where there is plenty of light, and as near to the pantry as possible, so as to save steps for the person using them. They should be removed to such a distance from the range that the persons using them will not be subjected to the heat of the fire, and should be set near a window, if possible, to secure plenty of ventilation. Sinks should not be encased in woodwork, but left exposed all around, so that no damp places can be maintained. Care should be taken to avoid leaving any crevice or cranny where dirt can lodge or where vermin may breed. If the sink is furnished with a back of any material, the space behind it should be thoroughly filled with cement or plaster of Paris, or provided with a special air space for a free circulation of air.

Kitchen sinks should be supported by legs, or placed upon substantial brackets, at a height of about 30½ inches above the floor.

Wooden sinks are fitted with a waste pipe *A* and strainer *B*, as shown in Fig. 1. The waste pipe is of lead, and is flanged over and secured with copper tacks. The strainer is made of sheet copper, and is sunk flush with the bottom of the sink. The connection is made water-tight by setting the flanged end of the pipe in white lead. This connection can be strengthened by wiping a flange around the pipe at *C*, and fastening it to the woodwork.

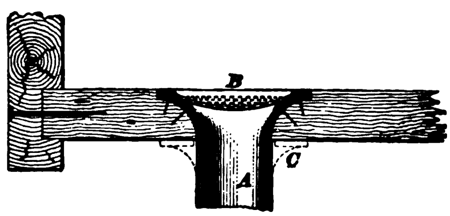


FIG. 1.

Wooden sinks may be lined with sheet metal, preferably copper, weighing 16 to 20 ounces per square foot. The bottom must be secured at several points by brass screws soldered over the top to prevent bulging when heated. Wooden sinks should never be used in dwelling houses because they harbor vermin so easily, and soon acquire a disagreeable odor.

Cast-iron sinks are provided with strainers, and the waste

pipe is attached as shown in Fig. 2. The lead waste pipe *A* is flanged over the conical nozzle *G* of the sink, and is held in place by the clamp ring *B* and the bolts *C*. To prevent water from leaking past the heads of the bolts and trickling down upon the outside of the pipe, washers of rubber or leather are set up tight by the nuts *H*.

The size and style of sink required will, of course, depend upon the service it must render, and upon the size and shape

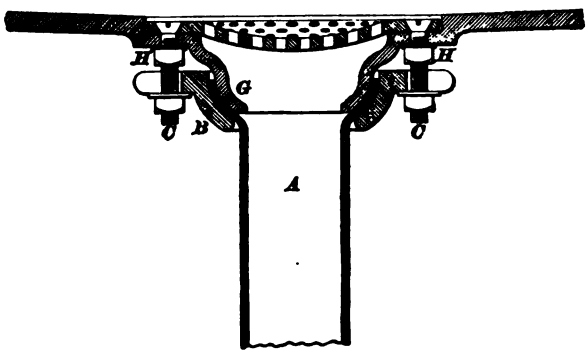


FIG. 2.

of the place in which it is to be set. This can easily be determined by reference to the catalogue of any reliable plumbers' supply house. For ordinary circumstances, a sink 36 inches long by 20 inches wide by 6 inches deep is generally employed. For general plain service galvanized cast-iron roll-rim sinks are usually specified. Porcelain sinks, however, are the best, and should be used on the finest work.

6. Butlers' pantry sinks are made of various shapes and materials. The most common are made of sheet copper tinned on the inside. They are either struck up from one piece of sheet copper, or are built of two or more pieces.

A copper pantry sink composed of one piece of sheet copper is shown at *a*, in Fig. 3. It is oval in plan and semioval in section. It is supported by a flange *b*, which is nailed down to the board *c* before the hard-wood top *d* is bedded down and secured in position

This form of pantry sink is always provided with an overflow horn, as shown at *e*, and a plug and socket waste connection in the center of the bottom, as at *f*. This is known as an *oval* pantry sink.

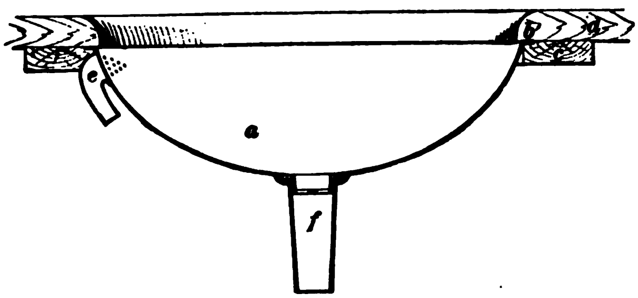


FIG. 3.

Flat-bottomed copper pantry sinks are built from flat pieces of tinned sheet copper. The seams are locked and sweated with soft solder. The bottoms are flat, and the sides are usually slightly rounded at the corners. They are also furnished with a flange *a* around the top, as in Fig. 4,

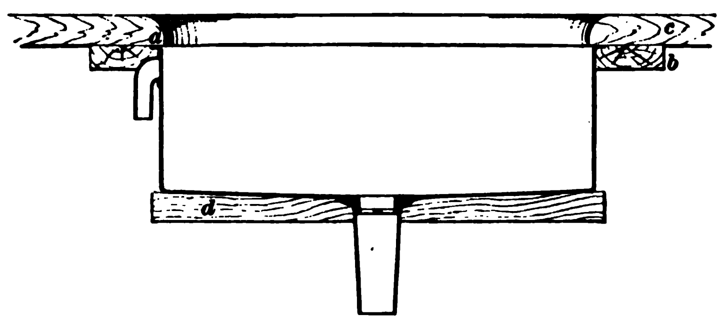


FIG. 4.

nailed to a wooden frame *b*, which prevents the flat sides from bulging. The hard-wood top *c* is bedded on the frame *b* with red or white lead putty, and secured with brass screws. The bottom of this sink should be supported by a shelf *d*, which is scooped out in the center, as shown, so that the bottom may be perfectly drained.

7. Porcelain pantry sinks are commonly made with a recess *A* in the back, which affords room for a standing overflow *B*, Fig. 5. This overflow tube is removable from the socket, and serves as a plug which can be pulled up to let the water out.

These sinks are usually fitted with a marble slab *D* and

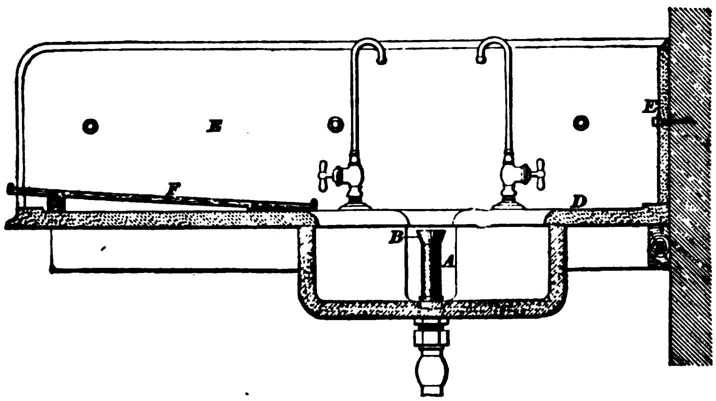


FIG. 5.

marble splash or wall plates *E*. A dish drainer *F*, made of wooden slats, or of rubber, is used to protect dishes from contact with the slab. The waste connection is similar to that of a wash basin.

8. Slop sinks are made of cast iron, plain, galvanized, or enameled, and differ from kitchen sinks chiefly in dimensions; being smaller in length and width, but of greater depth. They are usually set so that their rims are about 20 inches above the floor.

Slop sinks which receive chamber slops and sewage matter are provided with flushing rims and flush tanks, and are cleansed in a manner similar to washout closets. They are constructed with large traps, and are connected to the drain pipes in a manner similar to the connections of water closets. They are often supplied with hot and cold water faucets, similar to those used for sinks.

A **slop hopper** sink is shown at A, Fig. 6. It is provided with a strainer B, which can be removed to clear the trap below, and is supported directly upon a 4-inch trap C. The outlet end D of the trap is flanged so that it may be attached to a lead waste pipe. It may be had without the flange, when the trap is to be calked into the socket of an iron pipe.

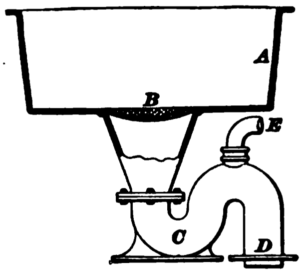


FIG. 6.

A 2-inch back-vent connection is made to the trap at E.

9. Wood as a material for sinks, has some advantages and many disadvantages. Dishes are less liable to break or chip, by coming into violent contact with it, than with a metal or porcelain sink. But it absorbs greasy liquids and becomes foul, emitting unhealthy odors. It fosters vermin, and becomes leaky from unequal shrinkage. If it is lined with sheet metal, the inner side of the woodwork has no chance to dry out, and it soon rots. If ventilating holes be made in the wooden bottom, they soon become infested with vermin.

The *cast-iron* sinks, plain or galvanized, seem to answer all requirements. To save the dishes from damage, the bottom of the sink may be covered by a grating of wood or rubber, which can be readily removed and cleaned. Other sinks may be fitted with the same device.

Enameled iron is very fine material for sinks while it is new. But the enamel will crack and admit moisture to the iron beneath, which will oxidize and detach the enamel, causing it to come off in flakes.

Steel sinks are light and cheap, but are not durable. They rust very rapidly. If they are enameled, the enamel on the bottom is soon cracked by the bending of the metal, caused by the weight of dishes in it, and it is soon spoiled, as before explained.

Earthenware or *brown glazed* sinks are about $1\frac{1}{2}$ inches

thick, and are glazed both outside and inside. They are quite heavy, and require an iron frame with legs to properly support them.

The chief merits of glazed earthenware or porcelain sinks, are (1) they are easily kept clean and free from smell; (2) they are practically imperishable.

WASH BASINS.

10. Wash basins are either round or oval in shape. The *oval* basin affords more room for the free use of the arms than a round one of the same capacity, and is, therefore, preferred.

Basins are measured over the outside of the top flange. *Round* basins vary in diameter from 12 to 16 inches. Oval basins are usually made in three sizes, 17 in. × 14 in., 19 in. × 15 in., and 21 in. × 16 in. The word *bowl* is now often used instead of basin. It refers only to that part of the fixture which holds the water.

Basins are made of iron, galvanized or enameled, and also of porcelain. The porcelain basins are made in plain white color, or they are decorated to any degree of elegance that may be desired. Wash basins are constructed in many ways. In the commonest variety, the bowl is separate from the slab or top, and the splash plate or back is also separate from the slab.

In other varieties, the bowl, top, and back are made in one piece of metal or porcelain.

11. Bowls are made with and without overflows, and the overflows are of several varieties. In Fig. 7 the overflow consists of a strainer A and a nozzle, or horn, B, to which a waste pipe is attached by a cemented slip joint, or by a rubber cone connection. The latter is preferable.

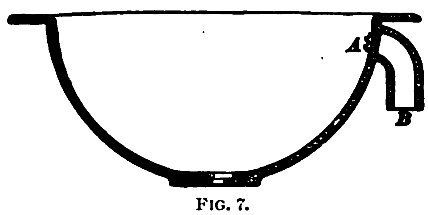


FIG. 7.

In Fig. 8 the overflow duct *a*, which is molded on the basin, leads into the waste outlet *b* through holes *c* in the connection under the rubber plug *d*.

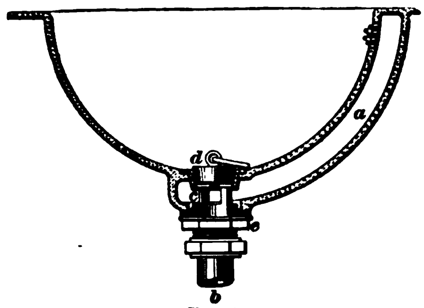


FIG. 8.

In Fig. 9 the porcelain bowl is constructed with a recess *a* to contain a combined standing overflow and waste plug *b*. The base of the waste plug is perforated and forms a good strainer, which can easily be cleaned by lifting out the entire waste plug and overflow arrangement. The

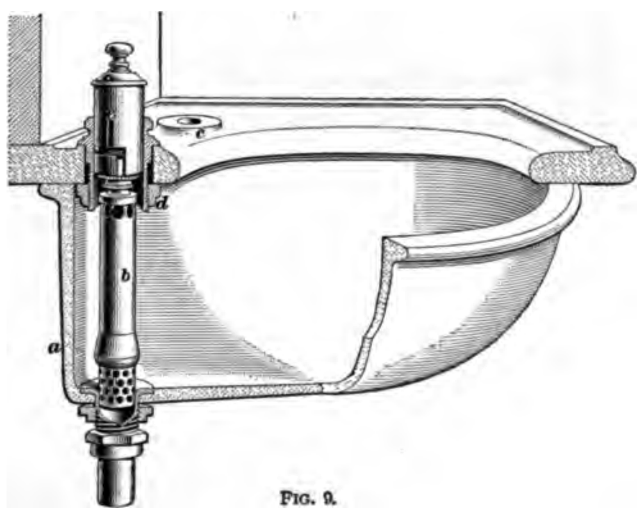


FIG. 9.

top of the plug *b* slides in a guide which is secured to the marble top *c* by a lockout *d*. The standing waste is suspended by a bayonet catch, as shown at *e*.

In Fig. 10, the bowl *c* is made plain without even a stopper, and has a strainer only. The stopper and standing overflow are contained in the tube *a*. The surplus water escapes through the holes *b*. Bowls are also made with

flushing rims, and the faucets are placed below the top, having only the handles in sight. The rim of the bowl is thus freed from all obstructions, and the hands of the bather cannot be injured by the nozzles of the faucets.

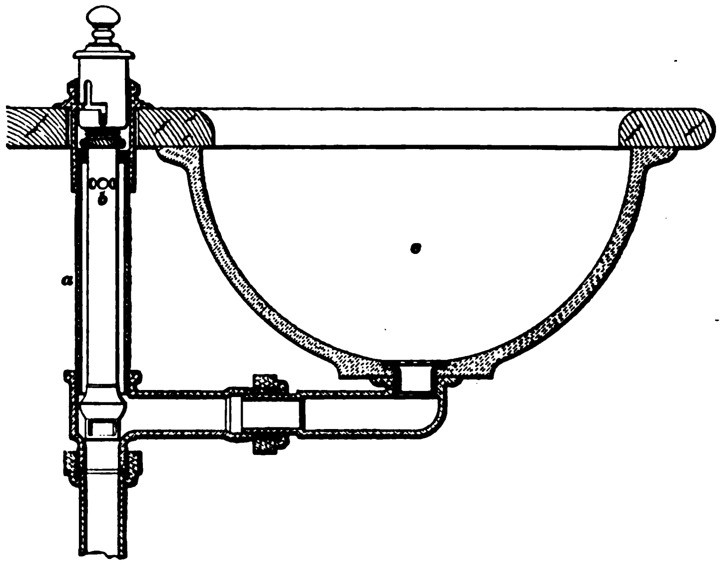


FIG. 10.

Wash basins are supported upon substantial wall brackets, or upon metal frames or pedestals. They should never be cased in with cabinet work, because such enclosures cannot be kept clean, and vermin will find lodgment in the crevices of the woodwork.

12. The **slab,** or top, should have a raised rim around its entire perimeter, so that splashes of water will drain back into the bowl. The holes for basin cocks and other attachments should also be surrounded by raised rims, for the same purpose. The holes for ordinary basin cocks should be made square to receive the square shank of the cock, and thus prevent it from turning.

The proper height of the top of the slab from the floor varies from 30 to $31\frac{1}{2}$ inches, the former being generally satisfactory.

The **basin cocks** should be attached to the slab with a lead washer between the marble slab and the nut underneath. The chain stay should be fastened in the same manner. The cocks should be set in plaster of Paris.

The connection between the waste pipe and the discharge outlet of the basin is commonly made by means of a screw coupling, as shown in Fig. 8. Great care must be exercised in screwing up this joint because the bowl is very liable to crack or break at this point. A thick gasket of soft rubber should be used between the lockout *e* and the porcelain.

The space between the splash plates, or back, and the wall should be completely filled with plaster of Paris, so that no crevice or hole is left for vermin.

BATHS.

13. The sloping end of a bath tub is called the **head,** and the vertical end is the **foot.** Tubs are made in three general styles, the *ordinary*, *French*, and *Roman*, the difference being in the shape.

The **ordinary** style has a round bottom, with sloping head and vertical foot.

The **French** style has a flat bottom and flat parallel sides, with rounded corners. The head slopes, and the foot is vertical.

The **Roman** style is rectangular, the sides, bottom, and ends being flat, with round corners. Both ends and sides are nearly vertical.

The ordinary style requires the least water, but the bottom being semicircular in form, is of inconvenient shape to stand upon.

The French tub affords more room for the bather, but requires more water.

The Roman bath gives most room for the bather. It is designed chiefly to overcome the unbalanced appearance which the other forms present when fitted up elsewhere than in a corner. In this style the faucets are nearly always located outside the tub, and the hot and cold water enters

through a single opening. The interior space is thus clear from all obstructions or projections upon which the bather might be injured.

14. The cheapest grade of baths are those made of wood and lined with zinc or tinned copper. Such baths are encased with wood finishings and have a special top made to fit the bath and the position in which it is placed.

Open copper-lined and aluminum-lined baths are clad with a steel or indurated fiber casing, supported on four cast-iron feet, and have the top rim 3 or 4 inches wide all around, attached to the bath.

A sheet of non-conducting material, such as asbestos, is put between the lining and metallic casing. The tin coating soon wears off, and exposes the copper. A harder and more durable coating is secured by nickel plating.

Bath tubs are also made of cast iron, and are used with or without protective coatings. The best grades of iron tubs are coated with porcelain enamel.

The finest grades of bath tubs are made of porcelain, or of a fine fireclay body with a heavy porcelain enamel. They are finished white, or are decorated to any degree desired. Iron and porcelain tubs are usually supported by detachable feet.

The waste pipe is always connected to the bottom of the tub, and should be provided with a strainer to prevent the passage of soap, rags, etc. into the trap.

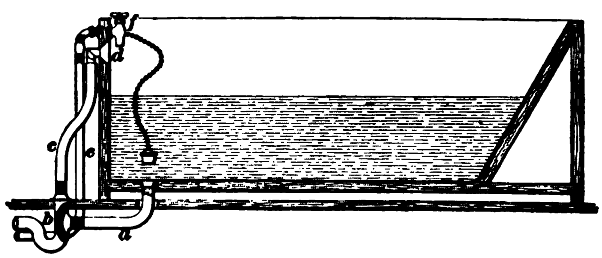


FIG. 11.

A common form of copper-lined wooden tub is shown in Fig. 11. The bath empties through the $1\frac{1}{2}$-inch waste

pipe *a*, through the 1½-inch half-**S** trap *b*, into the drainage system. A 1½-inch lead overflow pipe *c* connects the copper overflow pipe horn *d* to the trap. A ⅝-inch or ¾-inch lead pipe *e* supplies the bath with water through the bath cock *f*.

15. Standing overflow and **waste pipes** are frequently used, as shown in Fig. 12. The overflowing water passes

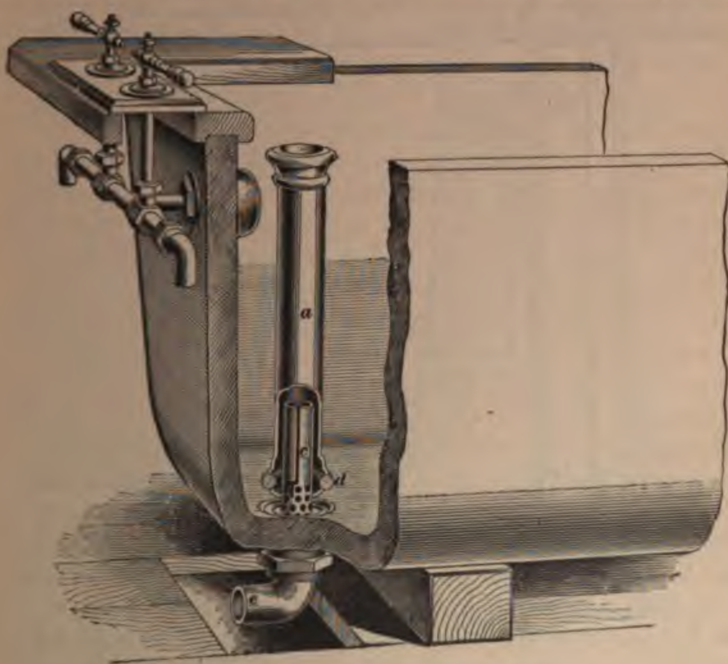


FIG. 12.

over the top of the standing tube *a*, and when the tub is to be emptied, the tube is pulled upwards, thus uncovering the perforations at the bottom of the inner tube *c*, as shown. The outer tube is provided with a rubber ring *d*, which makes a water-tight joint with the seat when it is dropped down upon the bottom. A bent coupling *e* is shown attached to the waste outlet. If desired, a straight coupling may be used.

16. A better combination of waste and overflow is shown in Fig. 13. The tube *a* is provided with a rubber ring *b*, which shuts down water-tight upon the seat *c*. The water rises between the tubes *a* and *d* to the same height that it does

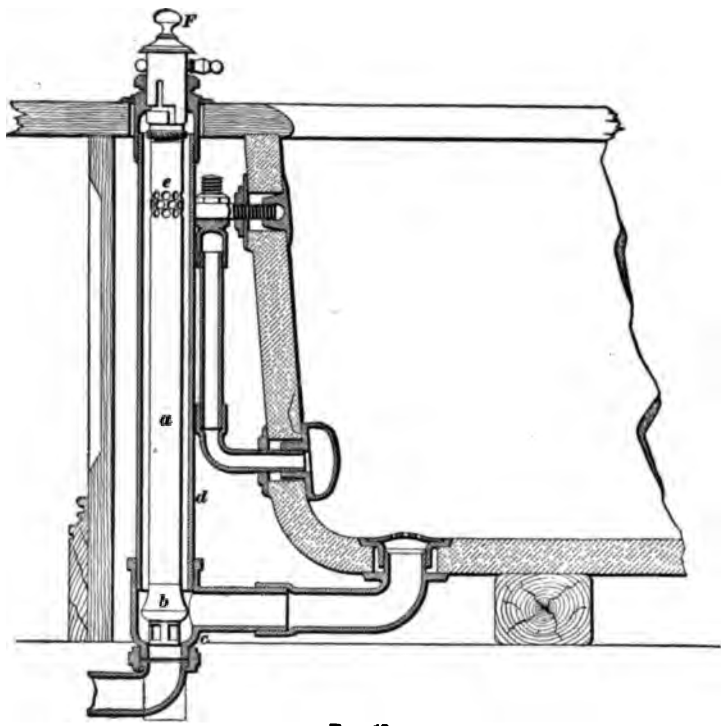


FIG. 13.

in the tub, until it reaches the perforations *e*; it overflows through these and passes down the interior of *a* to the waste pipe. The inner tube is provided with a handle *F* having a suitable slot and catch by which it can be lifted and suspended, as shown.

These combined waste and overflow devices are adapted to all kinds of bath tubs, whether of wood, metal, or porcelain.

17. The hot and cold water may enter the bath through separate faucets, but are, however, generally delivered to

the bath through a single bath cock composed of the hot and the cold shut-off valves joined together into one discharge nozzle. Such a fixture is known as a *combination bath cock;* it is usually nickel plated. The valves of the cock may be inside or outside the bath. Ground key cocks are seldom used as bath cocks. Fuller and compression valves are mostly used.

The faucets which are used to control the water supply are of two kinds. Plug cocks are used only on very low pressure work; compression cocks are mostly used. The hot and cold water faucets are commonly made in one piece, with a single discharge nozzle.

In the best grades of fittings, angle valves with brass screw-joint connections are used, and they are arranged to deliver water into the tub through the same nozzle, which should enter near the bottom of the tub if it is especially desirable that the water should fill the tub quietly. All the valves and pipes are thus located outside of the tub, and the whole interior space is free of obstructions.

Sometimes the hot and cold water faucets are connected to deliver into the outer shell of the standing waste, so as to supply the tub through the waste-pipe strainer. This is a bad plan, because when the tub is emptied the water passes out first and all soap or refuse goes last. This tends to lodge in the waste pipe, and it will be washed back into the tub, if the fresh water is introduced in that way. In buildings where there is a liability of the water supply being shut off while a bath is in use, the water should enter the bath at a point above the overflow openings. This will prevent it from being siphoned back into the water pipes.

18. Fig. 14 shows the arrangement of the connections to a Roman porcelain bath *A*. The standing waste *B* and the supply faucets *C* and *H* are placed at the side of the tub, between it and the wall. The mingled hot and cold water enters through the single nozzle *J*. *C* is the hot-water faucet, *D* is the hot-water circulation pipe, *E* the waste pipe, *G* the trap, *F* the trap vent, and *H* the cold-water faucet. The standing waste *B* is shown in section in Fig. 13.

19. Metal and porcelain tubs are made with two styles of rim, called plain or roll. A plain rim is shown in Fig. 13, and a roll rim in Fig. 14.

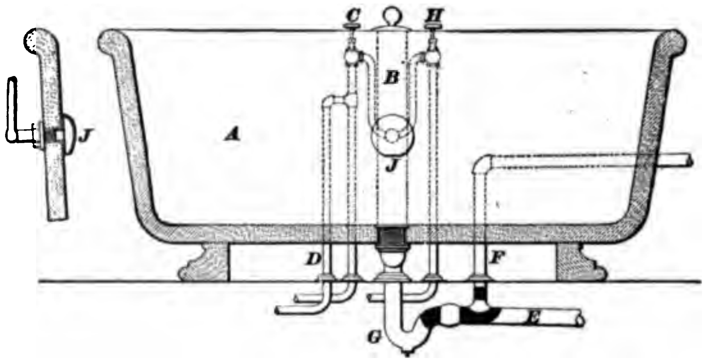


FIG. 14.

Bath tubs which are to be cased in are usually set on a copper or lead base. Those which are to be left open are generally set upon marble safes or upon a floor of some impervious material. Marble safes are usually dished out to a depth of $\frac{1}{4}$ or $\frac{3}{8}$ of an inch, and have a brass strainer connection to a waste pipe. Tubs should always be set with a small inclination, so that the water will drain properly towards the waste strainer.

The sizes of copper bath tubs range from $4\frac{1}{2}$ to 6 feet long, 24 to 26 inches wide, and 20 to 22 inches deep. Iron bath tubs are usually about 19 inches deep. Porcelain baths are wider, being usually 30 inches at the head and 24 inches at the foot, and are about 22 inches deep. They are quite heavy, a tub $5\frac{1}{2}$ feet long weighing about 600 pounds.

20. **Sitz,** or **seat** baths (see Fig. 15) are usually of smaller dimensions, being from 24 inches to 27 inches long, 22 inches wide, and 12 inches to 17 inches high at the front edge, when set up. The back is usually 6 inches, or more, higher than the front.

The sitz bath is fitted up with hot and cold water and waste connections in a manner similar to those shown in

Figs. 13 and 14. The hot and cold water valves and the stand pipe are rigidly secured to the side of the bath by a brace *a*. The hot and cold water mixes and enters near the bottom by the tube *b*.

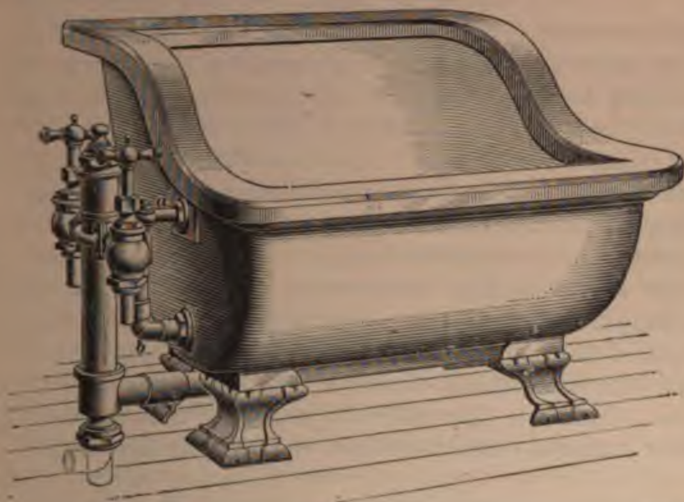


FIG. 15.

21. Foot baths are of about the same dimensions as seat baths; some, however, are only 17 inches by 19 inches and 10 inches deep. Seat and foot baths are constructed of the same materials, and are connected to the waste pipes in the same way, and are provided with the same fittings as the full-size baths.

22. Shower Bath.—The apparatus for a shower bath consists mainly of a large sprinkler, which delivers the water downwards in fine streams like a shower of rain.

The chief objection to plunge baths is that skin diseases are liable to be transmitted from one bather to another, unless the bath is thoroughly scrubbed after each bather has used it. For this reason, plunge baths are objectionable for public use; they are, however, considered quite safe for family use.

Hospitals, asylums, etc. must be provided with a large number of baths to accommodate the patients, and as each plunge bath occupies a large area (about 12 square feet), it is often found that sufficient space cannot well be obtained for the desired number of baths. In such cases, spray or shower baths, or a combination of both are often used. A shower bath consists of a sprinkler or shower nozzle attached to the end of the water-supply pipe, at a point about 7 or 8 feet above the floor, which is made waterproof and furnished with safe strainers at suitable points. The chief merit of the shower, or **rain bath,** as it is sometimes called, is that excretions or scales from one bather's skin cannot possibly come in contact with another bather. In a tub or plunge bath the water is cleanest when bathing is commenced, and at the period when clean water is most required, that is, at the finish of the bath, the water is most foul. In a rain bath, however, the water is clean at all times, because it is continually changing and none of the water comes in contact with the person more than once.

23. The shower-bath apparatus is so arranged that hot or cold water can be obtained as desired by regulating the discharge of hot and cold water cocks, or if steam is the heating agent, by regulating the volume of steam discharged into the cold water as it flows through the feed tube to the nozzle.

The best method of heating the water by steam is to place a copper or brass tube inside the cold-water feed-pipe, admit steam into the top and have a drip pipe from its base to carry off the water of condensation. The cold water becomes heated as it flows around the steam tube towards the nozzle. A graduated disk, representing the resulting temperatures when the valves are opened, should be attached to the steam valve so that the handle can be turned just enough to admit sufficient steam to give the desired temperature to the water. As a safeguard, however, a thermometer should be attached to the water pipe before it reaches the nozzle.

24. A **needle** and **spray bath** consists of a frame of perforated pipes, which partially surrounds the bather. The water is projected horizontally in fine streams or spray upon all parts of the body above the knees.

25. The **douche** is designed to project a stream of water upwards from the floor, either in a solid jet or in a spray. The jet is often attached to the strainer, which is set in the middle of the safe. All three varieties are often combined with the shower baths.

All jet or spray baths are provided with suitable hot and cold water pipes, which deliver the water into a mixing pipe before it leaves the jet. The mixing pipe should be provided with a thermometer, so that the temperature may be regulated before the bather exposes himself to the water. The thermometer must be so enclosed that its bulb or mercury chamber is in actual contact with the water, otherwise the indications will be very unreliable.

If the entire bathroom floor is not water-tight, a rubber cloth curtain should be hung by rings from a suitable rod overhead, so that it can be drawn together and be made to enclose the whole apparatus. This will prevent the water from falling outside of the safe in which the apparatus is located. The curtain should be open at the top.

Jet and spray baths are frequently set up within a stall or alcove, which is lined with marble slabs, or other impervious sheathing. They are also combined with bath tubs usually of the Roman or French style.

The floor room required for a shower or spray bath is usually from 3½ to 4 feet square.

26. **Bidets** consist of a pan or bowl having a seat like a water closet and a jet of water which is projected upwards. The pans are made of porcelain or of copper, and are also made in one piece with the support. They are usually fitted with hot and cold water connections and with a mixing pipe, which should have a thermometer attached to indicate the temperature of the water. Sometimes the pans are fitted

with a standing overflow and plug, by which water may be retained in the pan.

To have the use of a bidet jet without a special bowl, a bidet arrangement can be attached to an ordinary water-closet seat, by means of a clamp, secured to its under side. This arrangement, however, is liable to leak, and otherwise get out of order, and consequently, is seldom used.

LAUNDRY TUBS.

27. Wash tubs are made of various materials. The cheapest varieties are made of wood, the ends and partitions being rabbeted into the sides and bottom. The joints should be well painted with white lead, and should be drawn tight by means of iron bolts. Repeated drying and wetting soon spoils the joints and rots the wood. When they become leaky, past repairing, they may be lined with tinned copper, galvanized iron or zinc. As a rule, it is best to avoid their use.

28. Iron tubs, either galvanized or porcelain enameled, are cleanly, durable, and generally satisfactory.

The only drawback to enameled tubs is that the enamel will crack eventually and peel off. The corners are all rounded and no crevices exist in which dirt may accumulate or which will harbor vermin.

29. Porcelain tubs, or the brown glazed earthenware tubs, are very heavy, and require a substantial iron frame to support them. They are very durable and are easily kept clean. The corners are all rounded off to prevent dirt from lodging therein. If finished flat on top they are usually supplied with wood rims of ash to protect their edges. The rims should be set in red-lead putty before being bolted down tight.

Porcelain tubs of the finest grades are usually finished on top with a roll rim.

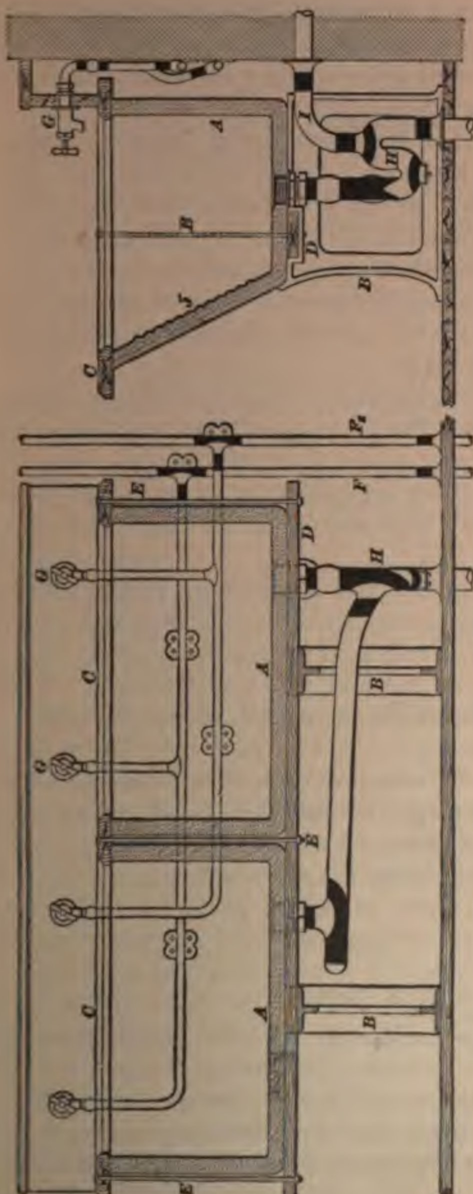


FIG. 16.

30. Tubs are also made of **soapstone** or **slate slabs,** which are joined by red-lead cement and are held together by rods and iron frames. Inferior soapstone will crack if subjected to hot water. These tubs are liable to accumulate grease and dirt in the sharp corners unless carefully cleaned.

31. In Fig. 16 is shown a set of two porcelain or glazed earthenware wash tubs *A*, *A*. They are set upon two cast-iron stands *B*. An ash frame *C* is bolted to a hard-wood strip *D* by long bolts *E*. Branches are taken from the hot and cold lead water pipes *F*, F_1 to supply the tub cocks *G*.

The waste water from the tubs passes through a

lead **S** trap *H*, connected as shown. The trap is protected against siphonage by a 1½-inch lead back-vent pipe *I*. One of the tubs has part of its inner surface corrugated as at *f*. This is often used as a scrub board.

Laundry tubs are sometimes fitted with wooden covers, which are hinged at the back. When these are used, the faucets must be placed within the tubs, the connections being made through holes in the back. This arrangement is objectionable, because the faucets occupy too much of the interior space of the tubs. The goods will catch and tear on the nozzles of the faucets, and the laundress is likely to bruise her hands upon them.

Tubs vary in length from 24 to 30 inches, and in depth from 14 to 16 inches. They are usually 22 to 24 inches wide at the top, and taper on the front side to 15 inches or more at the bottom. They are generally set up in groups of three. The rim of the tubs should be set about 32 inches above the floor.

Each tub should be fitted with an overflow, and an outlet plug and strainer. These may all be connected to one waste pipe. One 2-inch trap is sufficient for the three tubs. Each tub should have its own hot and cold water faucets. The faucets should, if practicable, be placed above the tubs, as in Fig. 16.

In fitting up a set of tubs, provision should be made for attaching a clothes wringer to the right-hand end of the right-hand tub, with a space of at least 2 feet between this tub and any wall to the right for a clothes basket.

WATER CLOSETS.

32. The duty of water closets is to thoroughly remove all filth that may be deposited in them. They must be free from all odors and must prevent the escape of odors from the soil pipe back into the dwelling. To meet these requirements, every closet must fulfil the following conditions:

1. *The water used for cleansing must be applied in such a manner that it thoroughly washes all the interior surface of the bowl.*

2. *The current must have sufficient force to detach all filth from the surface of the bowl.*

3. *The water must be of sufficient quantity to wash out all the filth and carry it beyond the trap and into the soil pipe.*

4. *When the flushing operation has ceased, the closet bowl and trap must be properly filled with fresh water, the foul water being entirely removed.*

The thorough washing of the interior surface of the bowl is accomplished by introducing the water through a **flushing rim.** This, when properly made, will direct the water in small streams over the whole internal surface. If any part of the surface be left unwashed, it will accumulate filth and emit bad odors.

The effectiveness of the current of water supplied by the flushing tank will depend greatly upon the shape given to the bowl, and upon the rapidity with which the water is projected into the bowl and trap.

33. A superior form of bowl is shown in Fig. 17. The bottom is of large area and is comparatively shallow. This shape is called a **washout closet.** Water is supplied to the closet bowl through the $1\frac{1}{4}$-inch flush pipe F, and the perforated flushing rim R, the largest volume entering the bowl at the back. The depth of water remaining in the bowl should be $1\frac{1}{2}$ to $1\frac{3}{4}$ inches at the deepest point. If the basin is deeper, the fresh water may pass under the solid excreta and fail to remove it before the flush is exhausted; and if the basin is shallower, the excreta may adhere so strongly that it cannot be washed away without using more water than can be allowed.

The soil-pipe branch and trap are ventilated by the *back-vent* connection B, which joins a vent stack. The bowl may be ventilated by attaching a pipe to the *local-vent* connection L. This, however, is seldom done unless the pipe can

be run inside or near a warm chimney. The lip S forming the seal of the trap A should dip not less than $1\frac{1}{2}$ inches nor more than $1\frac{3}{4}$ inches below the standing water in the trap. If the submergence of the lip be less than $1\frac{1}{2}$ inches, there is danger at times of its failing to properly seal the trap. The closet shown in Fig. 17 is called a *front-outlet washout water*

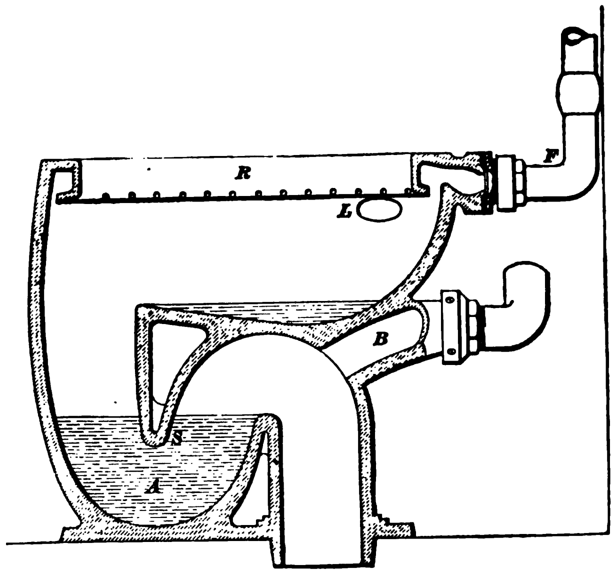


FIG. 17.

closet; it is also made with the outlet at the side, or at the back, as desired. The front outlet form is the best of the three. The closet is also constructed with the bowl separate from the trap, the bowl being of porcelain and the trap of iron. This permits the trap to be firmly calked into the cast-iron soil pipe, insuring a strong joint at that point.

34. The closet shown in Fig. 18 is called a **siphon-jet** closet. The contents of the bowl are sucked out by the siphon, which is formed by the two tubes C and D. Some of the water which enters the flushing rim A rushes down the tube G, forming a strong jet, which drives the water in C up into the space X and fills the tube D. As D is longer

than C, the two act as a siphon until the water in the bowl falls below the lip B.

The closet outlet horn F is attached to the soil-pipe branch. The back-vent pipe H ventilates the closet branch and prevents the bowl from being siphoned by the discharge of other fixtures into the same soil pipe.

Washout closets make some noise while emptying, but the best of the siphon-jet variety are nearly noiseless. This

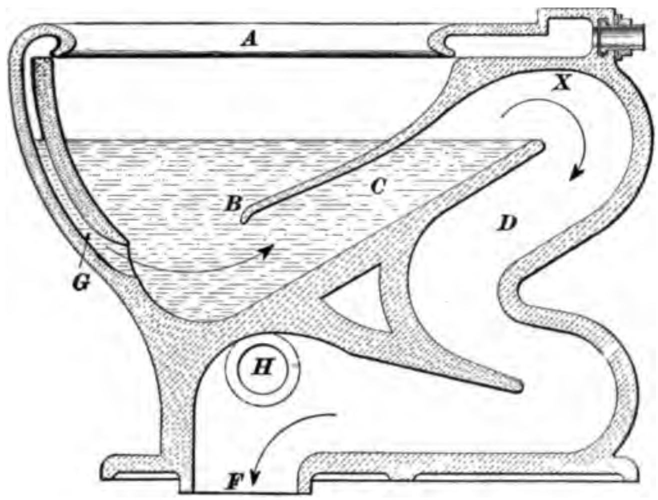


FIG. 18.

class of water closets is considered to be the best upon the market at the present time. The vent hole H is generally omitted in siphon-jet closet construction now, because it has been found by experience that the porcelain horns soon break off or leak.

35. In another variety, called **plunger** closets, the emptying of the bowl is controlled by a valve, or plunger, which also acts as an overflow.

The drawback to this style of closet is that the chamber in which the plunger works is imperfectly cleaned and is liable to become foul. Unless the plunger is lifted well up when emptying the bowl, pieces of paper or matches, etc.

are likely to stick between the valve and its seat, and prevent the valve from closing. This allows the water to leak out of the bowl, leaving it dry if the closet is supplied by a self-closing valve or by a small tank overhead.

If the closet is supplied by a ball cock placed in the plunger chamber, a uniform water-line will be maintained in the bowl, and if the plunger valve should leak, a waste of water would be the result, which cannot well be detected. This variety of closet should not be used. In fact, it should be removed from all buildings where repairs or remodeling is being done.

36. In the **hopper** closet variety, the bowl is of conical form and is attached to a trap of any desired shape above the floor. Such closets should be provided with flushing rims in all cases, if used inside a building. If they are used without a flushing rim, they become very foul and emit a constant stench. Their use is not recommended.

The **long hopper** is the same as the short hopper except that it has no trap above the floor. It is suitable only for outdoor situations exposed to frost.

The hoppers and traps are made of solid porcelain, or of iron, either plain or enameled. The traps for long hopper closets are placed underground, clear of the frost, a straight vertical 4-inch pipe joining the trap to the hopper.

37. Water-closet seats are of many forms, but very few of them have a proper shape. Several State Boards of Health have settled upon the shape shown in Fig. 19 as the best form, and recommend its general use. They say: "The hole in the seat should be long from front to back, but narrow from side to side. It should never be made circular, as carpenters will do, unless otherwise instructed. The proper dimensions are 11 inches by 4 inches. The edges should be moderately beveled. This shape will make the act of relief much

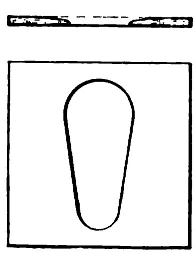


Fig. 19.

easier and tend greatly to prevent that painful disease—hemorrhoids."

Seats for *hopper* and *washout* closets are usually hinged to a back piece, which may be attached to the wall. The most improved patterns of closets are provided with lugs, to which the seat and cover may be hinged directly, and the seats are usually sold with the closets. All cabinet work or boxing of any kind should be avoided in setting up water closets.

No opportunity should be allowed for the lodgment of dirt or vermin. All the surroundings of a water closet should be kept strictly clean, and all arrangements of covers, pipes, traps, and safes should be made with that end in view.

Seats and covers should be provided with rubber blocks, or buffers of sufficient size and elasticity to prevent any damage by their falling down upon the porcelain bowl.

38. **The soil-pipe connection,** that is, the joint between the outlet of the water closet or trap and the soil pipe where it passes through the floor, is a matter of great importance. The common joint, which is made with putty, the flange being screwed to the floor, is rarely air or gas tight, although it may not leak water.

Porcelain closets are commonly attached by means of a

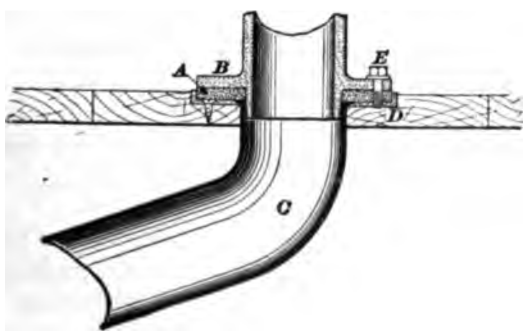


FIG. 20.

brass *floor-plate* joint, as shown in Fig. 20. The soil pipe branch *C*, if of lead, is soldered to a brass flange *D*, which is screwed to the floor. A rubber, or, better still, a red-lead

and hemp gasket *A* is put between the flanges, and the porcelain closet flange *B* is screwed down upon it by three or four screws or bolts, which should be of substantial size, and provided with washers, as at *E*.

Sometimes the lead pipe is flanged over on the floor, and the porcelain flange is set upon it with a bedding of putty. Such a joint will not remain gas-tight; it is worthless, and should not be allowed. Architects should specify the use of a brass floor-flange connection under each closet.

FLUSHING APPARATUS.

39. The purpose of a flushing apparatus is to thoroughly detach and remove all excreta, etc., from a water-closet bowl and drive it through and beyond the trap. If the excreta can be driven out of the water-closet branch into the main soil pipe, or main drain, it should be done, provided the water is abundant and not expensive; but it should invariably be driven out of the trap.

The efficiency of a flushing apparatus can be readily tested by coloring the water in the closet bowl with ink and throwing in some pieces of crumpled paper. Then start the apparatus. The flush may be considered satisfactory if no trace of ink or paper remains in the bowl, and if the trap and basin contain a proper quantity of clean water after the flush is over.

To secure a proper flush, a flushing tank should contain from 4 to 6 gallons of water, and it should be elevated at least 6 feet above the water-closet bowl.

40. A common variety of **flushing tank** is shown in Fig. 21. The valve *A* is pulled open by means of the lever *E* and hand chain *G*. The overflow *B* opens into the flush pipe *D* beneath the seat of the valve. The water rushes down the flush pipe only while the valve *A* is held open.

41. With this construction, the amount of water sent down may be too little to do the work properly, or the water

may be wasted by holding the valve open longer than is necessary. To remedy this defect, the **siphon** tank is used.

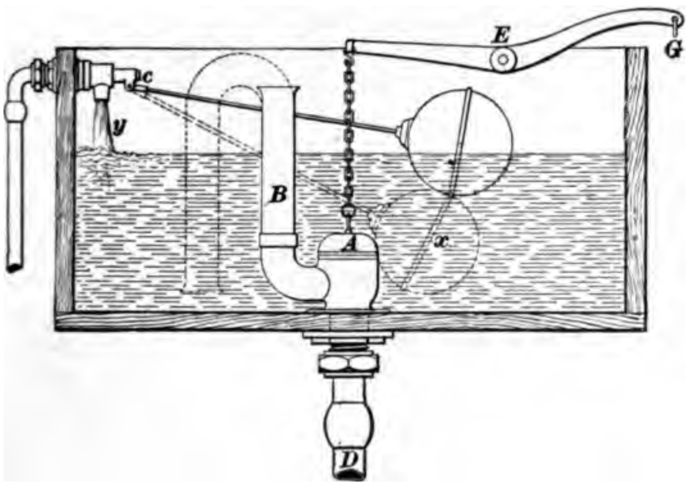


FIG. 21.

The construction of the siphon valve is shown in Fig. 22. It consists of an inner tube B and outer tube C which are united at the top by an air-tight cap D. The inner tube is provided with a rubber ring R, which forms the valve, and is seated upon the seat ring S. The two tubes thus form a siphon, the inner tube being the long leg. It is started into operation by lifting the valve off its seat. The water rushes down the flush pipe, draws the air out of B, and quickly fills both B and C with water. The valve is dropped back to its seat, and the discharge continues through B and C until the level of the water falls below

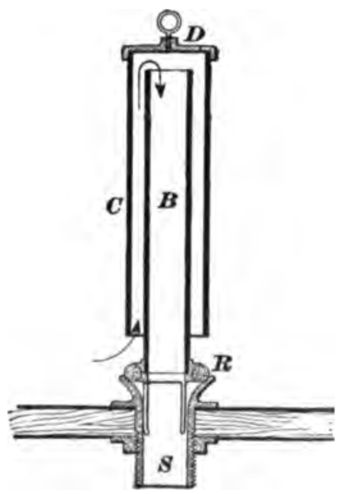


FIG. 22.

the lower end of *C*. Thus, if the valve be opened only a moment, or long enough to start the siphon, the tank will empty to the same point and the same amount of water will be delivered upon every occasion.

The device shown in Fig. 21 can be easily modified to accomplish the same result. The overflow pipe *B* may be prolonged and bent over, as shown by the dotted lines, thus forming a siphon.

42. Another variety of flush tank gives a large flush first and a smaller one immediately afterwards, the purpose of which is to properly fill the water-closet bowl and seal the trap. This is called an **after-flush** tank, and its construction is shown in Fig. 23. The tank is divided into upper

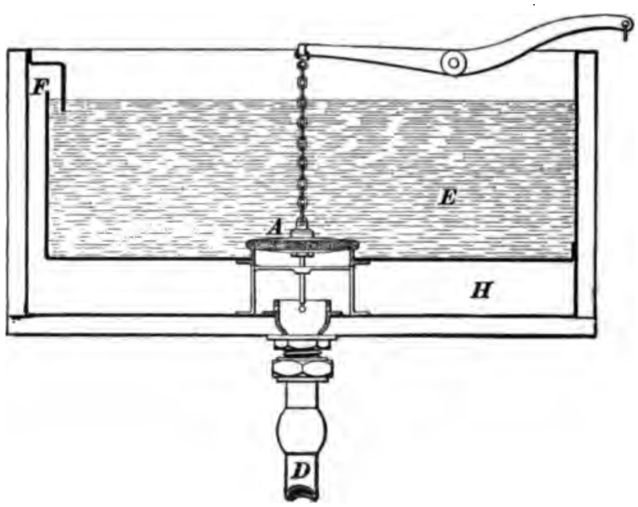


FIG. 23.

and lower chambers *E* and *H*. The valve *A* is made about 4 inches in diameter, and when it is opened, it passes water much faster than the flush pipe *D* can discharge it. The surplus fills the chamber *H*. When *A* is closed, the large flush ceases and the lighter flow continues until the chamber *H* is emptied. *F* is the overflow for the chamber *E*.

43. Flushing tanks may be dispensed with in some cases, by using a **closet valve** upon the service pipe, which, when opened, will remain open for a short period of time, and will automatically close itself, after permitting a quantity of water to pass which is sufficient to properly flush the bowl; this arrangement, however, is not as desirable as the overhead tank.

Flushing tanks for water closets and urinals are commonly made of wood and are lined with copper. They are also made of cast iron, and should be porcelain lined, enameled, or galvanized, to prevent rusting. Paint is not a sufficient protection for the inside of a tank.

44. Water closets should never, if it can be avoided, be supplied with water direct from city mains. They should in all cases be flushed by small overhead tank arrangements, unless exposed to frost, as the waste of water is thus largely prevented.

45. Periodical Flushing Tank.—This apparatus is designed for automatically flushing urinals, etc. at regular intervals. The form shown in Fig. 24 is called a **tilting** tank. The tank *A* is divided by a partition into two equal chambers. It rocks upon an axle *B*, and thus brings either chamber under the supply cock *C*. As the chamber fills, the center of gravity gradually changes until it passes over the axle *B*, when the tank tilts over, emptying one chamber and bringing the other into position for filling. The water being emptied suddenly, a rapid flow is produced, which is well suited for flushing purposes.

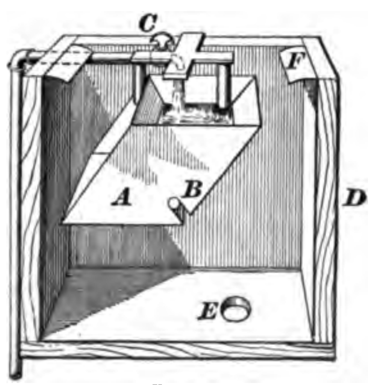


FIG. 24.

The bottom of the outer tank or receiver *D* should preferably be round, that the water may flow more rapidly and

more steadily down the outlet pipe E. Sheet-metal shields F prevent water from splashing over the sides when the tilting tank A is discharged.

LATRINES.

46. Latrines are a series of strong stoneware or cast-iron pans or closet bowls, usually porcelain lined, connected at their bottom by a large pipe which forms part of them and which has a gentle fall to the outlet end. At the lowest end is attached a plunger valve similar to that of the ordinary plunger closet. A trap, which disconnects all the latrines from the drains, is placed under the plunger valve. Water stands in the latrines to a height equal to that of ordinary wash-out closets, that is, about 5 or 6 inches below the seat. The plunger, which is hollow, acts as an overflow to the latrines.

When the plunger is raised, all the water in the bowls and their adjoining pipes is rapidly drained away, at the same time each bowl is flushed by a separate flush pipe, and when the plunger is replaced the latrines will again fill with water.

Latrines are used chiefly in public places, schools, railroad stations, factories, barracks, hospitals, etc., and they are usually under the control of a janitor.

The bowls should be so formed that excremental matter cannot touch their sides. It should drop in water which will partly deodorize it.

47. Trough closets are essentially composed of a long closet seat with a series of holes in it, having a suitable partition between each, and a cast-iron, brick, or earthenware trough under the seats, which should contain water for the excreta to fall into. The bottom of the trough should be round, and should grade down to the outlet which may have a plunger valve attached, as for the latrines. They are cleaned in a manner similar to latrines. The whole of the internal surface should be flushed by a perforated tube running all around its top, and the solid matter in the bottom should be forced towards the outlet by a large and rapid discharge of water from a jet in the upper end.

When trough closets are flushed from automatic tanks, the plunger valve is omitted, and water to a depth of about 2 inches only is permitted to remain in the bottom of the trough by the aid of an inclined lip near, its point of outlet, similar to the lip which retains water in the ordinary wash-out water closet.

When such closets are supplied with an abundant and rapid automatic flush, they do good work and require little attention.

URINALS.

48. Urinals are made of two styles, round and lipped. The latter are to be preferred, because they catch drippings better than do the round ones.

Urinal waste pipes are likely to become choked from organic matter which is deposited by the urine passing through them; and to flush them properly a considerable quantity of water is necessary.

The flushing pipe is usually connected at the top of the urinal, as shown at *A*, in Fig. 25. The flushing rim *B* of the urinal *C* distributes the water so that the whole interior surface is washed.

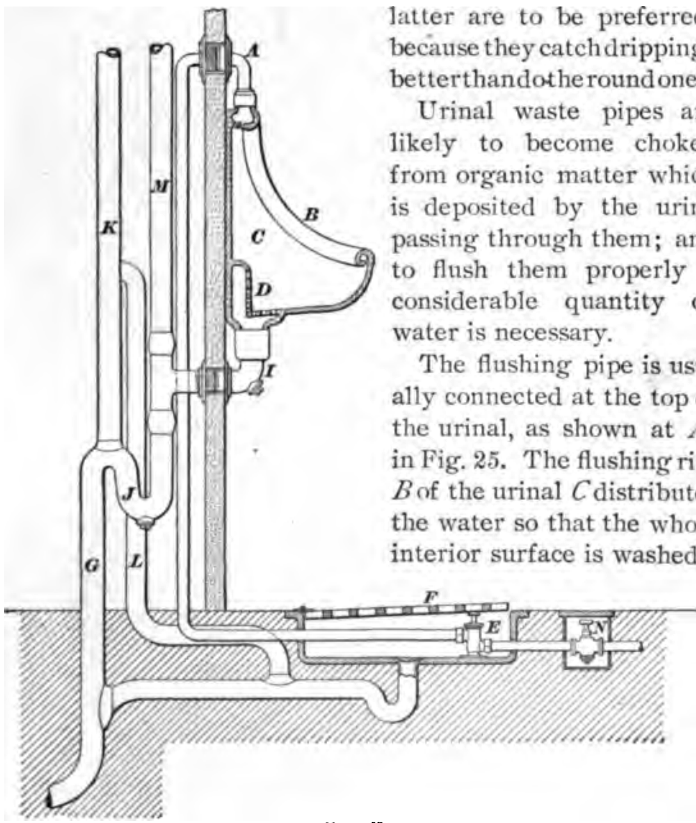


FIG. 25.

Urinals which have a strainer over the outlet should be provided with an overflow as at *D*. It is very difficult to prevent urinals from emitting offensive odors, unless they are provided with a local vent of sufficient size to draw a continuous current of air down through the outlet of the bowl.

49. If water is so scarce that a continuous flush cannot be permitted, the automatic arrangement shown in Fig. 25 may be used. The supply valve *E* is of the self-closing variety, and the valve stem projects upwards against a hinged platform or treadle *F*. To use the urinal, a person must stand upon the treadle, and that yields under his weight sufficiently to open the valve. The water flows as long as the treadle is depressed, and ceases as soon as the weight is removed from it. A small part of the water is used to flush the treadle box and remove the drippings that may fall into it. The waste pipes *G* and *I* and trap *J* should be not less than 1½ inches in diameter. The waste and trap from treadle box should be 1¼ inches in diameter. The waste pipe from the treadle box should be vented by a 1¼-inch pipe *L*, which should join the principal vent pipe *K*. The diameter of *K* should be not less than 1½ inches. The local vent or ventilating pipe *M* should be 2 inches in diameter, and care must be taken to get a good draft of air through it. The stopcock *N* is used to shut off the water supply.

Attachments which open the supply valve and allow the water to run, are sometimes fastened to the door of the stall in which the urinal is enclosed, so that a given quantity of water will be discharged into the urinal every time the door is opened. Consequently, the urinal will be flushed before and after use. The door is closed by a spring or weight.

KITCHEN RANGES.

50. There are so many different kinds of kitchen ranges on the market at present, that we will not attempt to describe them, except in a general way.

Portable ranges, or kitchen stoves, as they are often called, are commonly used in small framed residences, for heating and cooking purposes, also in places where the brickwork of the chimney is not wide enough to allow the range to be "built in." Portable ranges, therefore, stand on the kitchen floor, about 9 inches or more clear of the back wall. If the floor is made of wood, they should be set upon zinc or galvanized sheet-iron floor plates, which should project at least 1 foot out on the firebox end to intercept any live coal which may fall on the floor. Portable ranges are usually "single-oven" ranges; i. e., they are mainly composed of one oven, one firebox, and the necessary flues to conduct the heated gases around the oven. The principal objections to portable ranges are:

1. They occupy too much floor space.
2. They overheat the kitchens, and thus impair the health of the people who use them.
3. The stove-pipe connections are not only hideous, but are a source of nuisance and periodical expense.

51. Brick-set ranges, so called because they are set in brickwork, are generally employed in brick or stone buildings, and in such wooden buildings as are provided with specially wide chimneys. These ranges may be purchased either "single" or "double oven," or they may be had in rows of three or more, as the conditions may require.

52. Kitchen ranges should all be provided with some means for carrying off the vapors from cooking pots, etc., otherwise, the odors from the kitchen will permeate the whole building. To properly accomplish this, a special ventilating flue, at least 8 inches by 12 inches, should be built close to the smoke flue in such a manner that the hot gases from the range fire can heat the ventilating flue and cause a good draft. A sheet-iron **hood** is often used to draw the vapors together and guide them into the ventilating flue. When a special ventilating flue cannot be obtained, the next

best arrangement is to lead the vapors into the chimney flue through an ordinary wall register near the ceiling, a hood being employed like a canopy to hang over the range. When a hood cannot be used it is customary to arrange the **throat piece** with a slide, or hinged opening, as shown at *a* in Fig. 26, allowing the sheet-iron smoke pipe *b* to rise up in the chimney flue as high as possible without choking off the vapor vent. Any range can be selected from the manufacturer's catalogues, and the dimensions of the openings to receive them should be obtained from same, before the chimney is built, so that the range may fit snug when set in place.

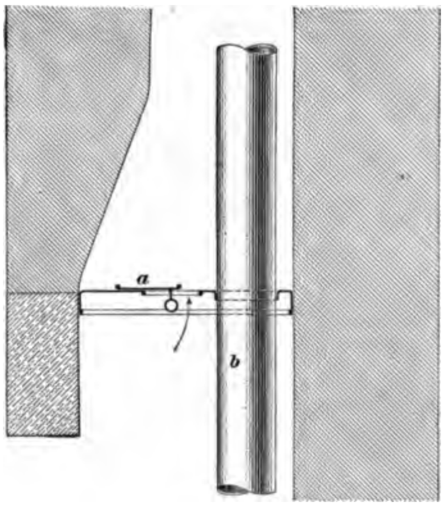


FIG. 26.

WATERBACKS OR WATER HEATERS.

53. Hot water for domestic purposes is commonly heated in the cooking range by means of a waterback, or by a coil of pipe which extends around the top edge of the firebox. A **waterback** is a cast-iron block provided with internal passages through which water can flow. It is made by coring out the interior at the time of casting, or by casting the block around a flat coil or loop of wrought-iron pipe, which is laid in the mold. The waterback covers one side of the firebox, and is usually tapped with two holes for 1-inch wrought-iron pipe. Waterbacks are exposed to severe internal strains, and the metal must be much thicker than is

required to resist the water pressure; they are designed to resist a pressure, when cold, of 700 pounds per square inch.

A **firebox coil** for heating water in place of a waterback, is usually made of copper tube, ¾ inch internal diameter and about ⅛ inch thick, placed on the inner edge of the firebricks.

54. Waterbacks are sometimes overheated and weakened, or are eaten away by internal corrosion, and if an extraordinary pressure is brought to bear within them, they will explode with disastrous effect. The damage which results from the explosion of a waterback greatly exceeds that from the bursting of a pipe coil, because of the greater interior area and greater volume of contents.

The capacity of a waterback is measured by its heating surface in square inches, reckoning only that side which is exposed to the fire. About 100 square inches of external heating surface are sufficient for a 40-gallon boiler, where water is plentiful, or a 50-gallon boiler, where water is scarce.

The quantity of water heated, the time required to heat it, and the quantity of water consumed, vary in every case. The size of waterback that should be placed in a range, depends upon judgment. A large boiler requires a large waterback, and a small boiler a small one. A large boiler and a small waterback means scarcity of *hot* water, or plenty of lukewarm water. A large waterback and a small boiler means boiling hot water, and rumbling, snapping, and cracking noises, formed by the formation of steam.

HOT-WATER BOILERS.

55. Boilers for domestic use are made either of copper, thoroughly tinned upon the inside, or of galvanized iron. They are usually set in a vertical position, but when circumstances require it, they can be operated horizontally. Boilers are also made double, one within another, to suit places where the water is drawn from two sources at different

pressures, and where one water heater must heat the water in both boilers.

The size of boiler which should be placed in a residence is a matter of great uncertainty. Experience shows, however, that a 40-gallon boiler is usually sufficient for a house having one bathroom, and one sink, a set of wash tubs, and a wash bowl. If there are two bathrooms, a 50 or 60 gallon boiler should be used. It is good policy to have the boiler a little larger than necessary, rather than small, particularly if the pressure is low.

Boilers may be covered with neat wooden lagging, composed of strips of pine or hard wood, $1\frac{1}{2}$ inches to 2 inches wide, $\frac{3}{4}$ inch or more in thickness, tongued and grooved, and confined by brass or galvanized iron bands. This will prevent the large waste of heat which occurs from radiation, and which goes far to make the kitchen uncomfortably warm.

Safety valves are not necessary when the boiler is connected directly, without the intervention of a check-valve or a reducing valve, to the street mains, or to the pipe from a tank, because the expansion of the water in the boiler is relieved by forcing a small amount back into the supply pipe. Where that method of relief is prevented by check-valves or other devices, safety valves must be used.

A vacuum valve must be attached, if a copper boiler is likely to be emptied and to have a vacuum formed within it; because the pressure of the atmosphere upon the outside will crush it, unless the vacuum be destroyed. A boiler which is supplied with an expansion pipe, i. e., the pipe which runs from the hot-water distributing pipe to a point over the supply tank and has its end open to the atmosphere, needs neither a safety nor a vacuum valve.

Boilers should be tested by warm water pressure to 150 pounds per square inch for general service. A test of 100 pounds per square inch is sufficient for working pressures of 30 pounds or less. For extra heavy working pressures, the boilers should be tested to double the working pressure, or to at least 100 pounds more than the working pressure.

The consequences of the explosion of kitchen boilers are

likely to be very serious, and the architect should insist that the manufacturer test every boiler to a proper test pressure, and guarantee it to endure that pressure.

Iron boilers are galvanized after they are riveted together. The interior can be examined by pushing a lighted candle inside and looking through the pipe holes.

Boilers which are constructed with a single line of rivets in the longitudinal seam, are called **single riveted** and are suitable for moderate pressures only. Those having two lines of rivets, in zigzag or alternate order, are called **double riveted** and are suitable for heavy pressures. A single row of rivets is sufficient to secure the head or the bottom.

56. The proper mode of connecting up vertical boilers is shown in Fig. 27. The cold-water pipe X should enter at the top of the boiler and end at the line $a\,b$, which should be about 3 inches above the level of the water-back WB. When the pressure is shut off, the water is likely to be drawn out of the boiler by the opening of a faucet at a lower level, as at C. The pipe $X X_1$ then acts as a siphon, and will run the water out until its level falls to the end of the pipe X_1. If X_1 extends to the line $c\,d$, the waterback will be drained, which is dangerous, for unless the fire is drawn, the waterback will become overheated, and when the cold water is turned on, it will be likely to crack or explode. All danger from siphoning can be avoided by drilling a small hole, about

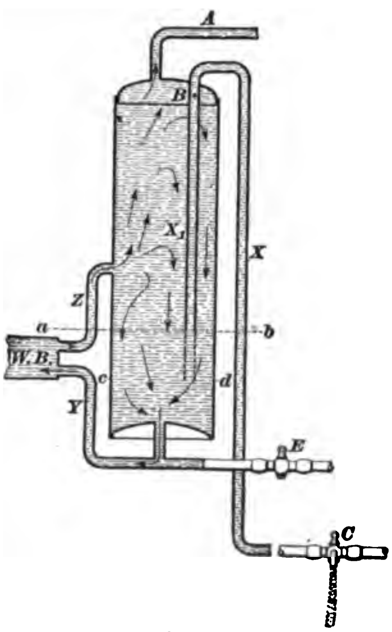


FIG. 27.

$\frac{1}{8}$ inch, in the pipe as at *B*. The hot-water pipe *A* is connected at the extreme top part of the boiler.

The direction of the circulation is shown by the arrows. Connections are made to the waterback by two pipes *Y* and *Z*. The pipe *Y* should be connected to the bottom of the boiler, and should be inclined upwards towards the waterback. The pipe *Z* receives the hot water from the waterback, and should be inclined upwards towards the boiler. It should be connected to the boiler at a point not less than one-third the height above the bottom, and it should be at least 1 inch internal diameter for a 40 to 60 gallon boiler.

A blow-off cock, to remove mud and sediment, should be provided, as at *E*. This may empty into a sink, or may be connected to the waste pipe on the house side of a fixture trap.

Boilers connected in this way require considerable time to heat their entire contents so that hot water will readily appear at the faucets.

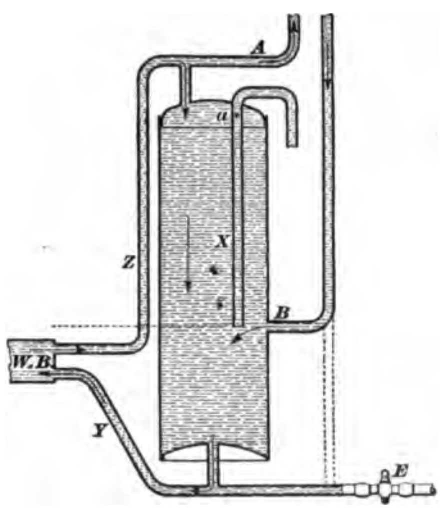


FIG. 28.

57. When it is desired to get hot water without delay after starting up the fire, another system of hot-water connections is resorted to. This is shown in Fig. 28. The pipe *Z* is connected directly to the hot-water distributing pipe *A*, as shown. Thus, the hot water as it comes from the waterback can go direct to the fixtures, or if none is wanted, it can go into the boiler.

When hot water stands in the pipes for any considerable time, it cools off, and several gallons of cold or lukewarm water must be drawn from the faucet before hot water

appears. This is always annoying, and when water is scarce, it is very troublesome. To secure hot water at each fixture promptly upon the opening of the faucet, a **return** or **circulation pipe** must be used. This pipe is joined to the hot-water supply pipe near each fixture, and it should always be one or two sizes smaller than the hot supply pipe. The return branches are united to a descending pipe, which enters the boiler at *B*, Fig. 28, about one-third up. It is not good practice to connect the return pipe to the extension of pipe *Y* as shown by the dotted lines.

Check-valves should not be employed in this return pipe, because the circulating current is too weak to operate them.

The hot water rises in *A* and returns in *B*, thus maintaining a circulation sufficient to keep *A* filled throughout its entire length with hot water of satisfactory temperature.

58. Horizontal Boilers.—These are employed where there is no room to stand a vertical boiler. The manner of connecting them is shown in Fig. 29. *A* is the hot-water

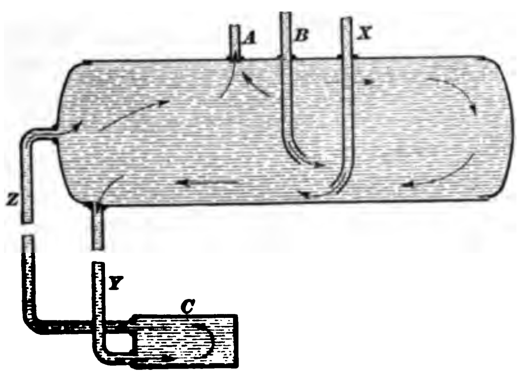


FIG. 29.

supply pipe; *B* is the return pipe; *X* is the cold-water supply; *Y* and *Z* are the connections to the waterback *C*. The waterback should be at a lower level than the bottom of the boiler. The arrows show the direction of the circulation. The boiler may be supported upon brackets or may be suspended

by bands from overhead floorbeams. Horizontal boilers are usually suspended immediately over the kitchen ranges.

59. Double Boilers.—These are used to heat water which is supplied from two separate sources; usually one part of the boiler receives water from street mains, and the other is supplied from a tank. The two boilers are combined in one structure, as shown in Fig. 30. The boiler *B*, which is fed from the tank and sustains the highest pressure, is placed inside of the low pressure boiler *A*. The inner boiler is heated by the water in the outer one; thus both are operated with one waterback or heater. The connections to each boiler are made in the same manner as for an ordinary vertical boiler. *C* and *D* are the pipes to the waterback; *E* is the hot-water supply pipe to the lower stories or street pressure system; *F* is the hot-water supply to the upper stories or tank pressure system; *H* is the cold-water supply from the street mains; and *G* is the cold-water supply from the tank. *L* is a blow-off or sediment cock for the inner boiler, and *M* is a similar cock for the outer boiler. It should be noted that the inner boiler cannot be emptied without opening both *L* and *M*, and thus emptying both at the same time.

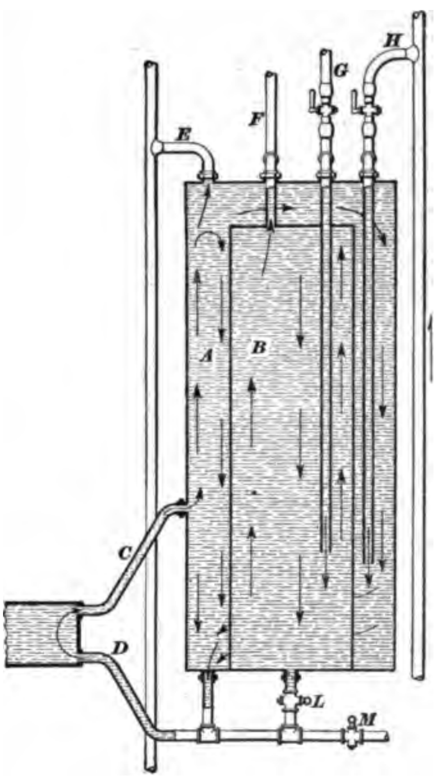


FIG. 30.

The inner boiler should be of copper, and should be thoroughly tinned both inside and out.

60. Boilers Heated by Steam.—The hot-water supply for large buildings, hotels, etc. is sometimes heated by steam, as shown in Fig. 31. A horizontal boiler *A* is shown, but a vertical one can be used equally well. The steam is taken in through the valve *C*, and after passing through the coil of brass or copper pipe *D*, it passes off in the form of water through the pipe *E* to a steam trap. *B* is the cold-water supply pipe; *F* is the hot-water supply to the fixtures; and *G* is the return pipe from the fixtures.

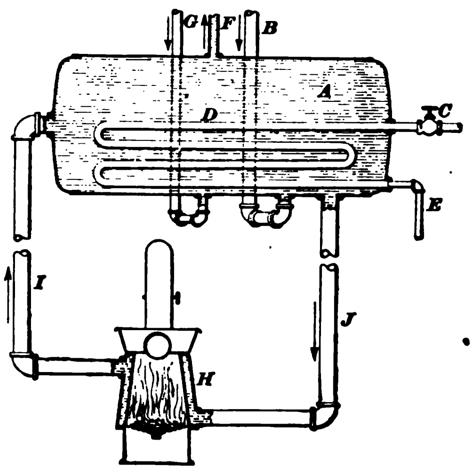


FIG. 31.

The supply of steam for heating the coil may be shut off at times, or may be withdrawn during the summer. In that case, an auxiliary heater must be provided. The arrangement of the heater is shown also in Fig. 31. It consists mainly of a furnace chamber which is surrounded by a cast-iron water jacket *H*. The cooled water flows down the pipe *J*, and becoming warmed in the jacket *H*, flows upwards through the pipe *I*, thus maintaining a constant circulation.

STORAGE TANKS FOR WATER.

61. Tanks to store water for supplying plumbing fixtures must be set at least 6 feet above the level of the highest point to which water is to be supplied by them.

The choice of material to be used in the construction of a

tank is governed by the use which is to be made of the water, and also by the size of the tank.

62. For storing drinking water, **circular wooden tanks,** made of well jointed staves, thoroughly hooped, are used whenever circumstances will permit. Cedar is commonly used in their construction, since it is easily made water-tight and is very durable. Wooden tanks are chiefly used for out-of-door purposes, being often placed above the roofs of the buildings they are intended to supply.

Tanks of extra large capacity are frequently made of wrought-iron plate, and are circular in form. They may be rectangular in form if desired, but for equal capacity rectangular tanks are more expensive, because of the elaborate system of bracing which is required to keep them in proper shape. Iron tanks require protection against frost; for, since iron is a good conductor of heat, the heat of the water is rapidly transmitted to the outer air, and the water contained in the tank freezes. This does not occur to such an extent in wooden tanks.

63. Rectangular wooden tanks are very difficult to keep water-tight; consequently, they are usually lined with sheet metal. In a lined tank, the wooden sides and bottom have only to support the sheet-metal lining and resist the hydrostatic pressure. They are not required to be water-tight.

The sides and bottom should be $1\frac{1}{2}$ inches thick and upwards, according to the distance between the supports. The supports should be placed so closely together along the sides and ends, and across the bottom, that the planking will not spring between them.

In Fig. 32 is shown two methods of bracing the sides of a rectangular tank. The sides are prevented from bulging outwards by vertical posts A and A_1. In the method shown at the left, the post A is secured in position by mortise and tenon joints C to the horizontal timbers D, D, and are wedged tight by wooden wedges E, E. This kind of bracing

is not so strong as that which ties the post A_1, which is held in position at top and bottom by wrought-iron bolts or rods *B, B*. The lower rod should be stronger than the top rod. Should the tank be deep, extra rods should be run through

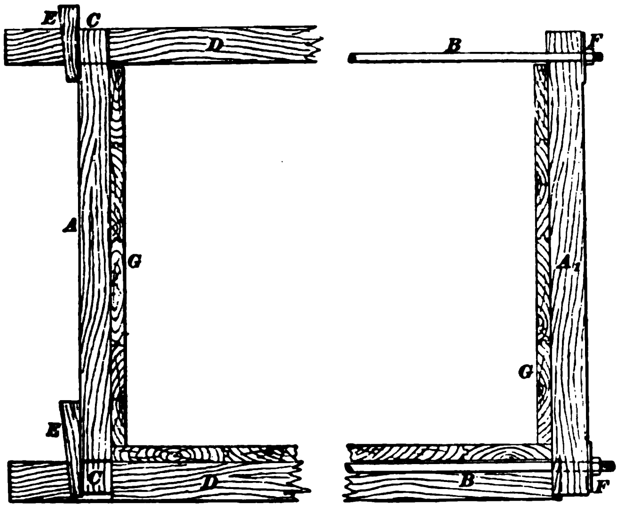


FIG. 32.

the body of the tank to tie in the center of the vertical posts. Iron fish-plates or large washers *F* must be used to prevent the nuts from cutting into the wood. All the bracing timbers must run crosswise with the lining boards *G*.

The ends of the tank must be supported by posts and tie-rods, as the sides are. The bottom tie-rods will necessarily pass through the sills. The sills must never be notched to pass the rods, but holes for that purpose should be bored along the center line of the timber. It should be remembered that the pressure upon the sides of a tank depends wholly upon the *depth* of the water, and is unaffected by the width of the tank, while the pressure upon the bottom depends upon its area and the depth of the water. Thus, with an equal depth of water, a tank but 1 inch wide or less will have exactly the same bursting pressure upon its sides as one 10 feet wide or more.

Care should be taken to provide a floor, or other supports,

beneath a tank of sufficient strength to support it without sagging.

64. Tanks above roofs are usually fitted up a few feet above the roof in order that connections may be conveniently made underneath, and that the tanks may be protected from frost by suitable casings. Tanks in sheltered positions are usually set on flat floors, etc., with the pipe connections leading from their sides.

A tank which is outside, or on top of a building, should be provided with a wooden housing, to protect it from frost and from the heat of the sun. Care must be taken in locating a tank to avoid the vicinity of soil pipes and vent pipes, and all possible sources of contamination by foul air. All storage tanks, either inside or outside of buildings, should be provided with tight covers to prevent the entrance of dust, etc. The covers should be carefully ventilated, close-meshed brass gauze being used for covering the apertures used for ventilation.

65. The **overflow pipe** should be made with a wide mouth. The supply pipes to the kitchen boiler and to the cold-water system, are attached to the bottom. The end of the cold-water supply pipe should be extended at least 3 inches higher than the end of the pipe to the boiler. This insures that the cold water will fail at the faucets before it fails at the boiler, and that the boiler shall be supplied as long as the tank contains any water.

If the tank is supplied from the street mains, the supply should be controlled by means of a ball-cock and float; if supplied by a pump, the water should be delivered over the side of the tank.

To give notice when to stop pumping, a small overflow pipe, or *telltale*, is connected at high-water level, and its outlet is placed at some visible point near the pump. When the tank is properly filled, water will flow from the telltale and thus indicate the fact to the operator at the pump.

66. Tanks receiving their water supply intermittently, as from pumps which have to supply a residence with water

and also supply water to a barn, and for sprinkling lawns, etc., are usually provided with two outlet pipes, one of which is connected at a higher level than the other. The object of this arrangement is to cause the supply to the barn, etc. to fail first, as the tank becomes exhausted, and to hold a definite quantity of water in reserve for the use of the dwelling. The stoppage of the water supply to the barn serves as a notice to the attendant to start the pump.

If rain water be led directly from the roof gutters into a tank, the conducting pipes should not only have strainers in the gutters, but should also have a movable basket strainer of fine mesh, hung on the mouth of the pipe, where it can easily be taken off and cleaned. The coarse strainer in the gutter will keep back leaves and twigs from trees, birds, etc., while the small mesh strainer hung on the tank end will catch all the smaller matter, which would otherwise accumulate in the bottom of the tank, decompose and contaminate the water.

67. All tanks should have a washout cock of large caliber attached to the lowest part of the bottom, so that mud and sediment can be scrubbed and conveyed through it to some convenient point of discharge. Or, the overflow pipe may be taken through the bottom of the tank and continued up to 2 or 3 inches below the top, with a hollow brass waste plug and socket connection at the bottom, so that the standing overflow within the tank can be lifted out of the ground socket, and the tank thus emptied. The upper end of the standing overflow should have a funnel mouth.

Large tanks are usually provided with a device to show the level of the water in them. A float commonly made of wood rests on the water, and is connected by a wire or cord and guide pulley, to a small weight or pointer which slides over the graduated scale, which is located at some convenient point of observation.

68. The **size of tank** required for any building depends chiefly upon the nature of the water supply, the character of

the building, and the rapidity with which the water will be used.

If the water supply is from street mains, the tank capacity for residences should equal at least a 2-day supply, estimating at the rate of 25 to 30 gallons of water for each occupant.

If the tank is supplied by a windmill, hot-air engine, or other pump, and if it is located in the country, the tank capacity should be much greater; it should be good for a 5-day supply at least.

69. The **amount of water** which is actually required per day, has been found by measurement to be about 25 gallons for each person, large or small.

This amount is approximately made up as follows:

1 quart for drinking.

1 quart in food.

1 gallon for washing dishes and cooking utensils.

2 gallons for house cleaning.

3 gallons for washing clothes.

5 gallons for toilet purposes.

The remainder is used for bathing and water closets.

A horse will drink about 7 gallons per day and will need 4 gallons for washing.

A carriage will require from 9 to 16 gallons for washing.

A cow will drink 5 to 6 gallons per day.

70. If water is to be stored in a tank for drinking and cooking purposes, great care must be taken to make the *tank lining* of a material that will be insoluble in the class of water contained. It is found that *sheet copper* tinned on the inside forms an excellent lining, and is often used in wooden tanks.

Tanks made of impervious materials, such as porcelain, glass, slate, stoneware, etc., are also used for storing drinking water. The slabs of which the tank is composed are usually made water-tight at the seams with red or white lead. and are held in position by staybolts, which bind the opposite sides and resist the water pressure.

71. A sheet-metal tray, or **safe**, is usually placed under water tanks in buildings to prevent damage by leakage or overflow. The safe is usually turned up 3 or 4 inches all around its edges, and is provided with a $1\frac{1}{4}$ or $1\frac{1}{2}$ inch **safe waste pipe** discharging to the atmosphere at some convenient point, such as over and into a sink.

Sheet lead, zinc, and galvanized iron are unsuitable for tank linings, because they will poison the water. Tanks may be constructed of plain black sheet or tank iron, or of cast iron. These will not injure the water unless it stands a long time, in which case it will be discolored, and will acquire a nauseous taste.

If rain water, or other soft water, is to be stored in a lead-lined tank, the lining should first be thoroughly covered with a coat of lime wash. This will form a coating of carbonate of lead, which will retard the corrosion of the lead and the contamination of the water.

LOCATING FIXTURES.

72. Fixtures should be so located in a building that the pipes necessary to supply them with water, and carry off the discharges from them, shall not be run in exposed walls; although in many cases it is safe to run the pipes against the walls, if the pipes are open to the warmth of the room. They should be located in places where light and ventilation are abundant.

Sinks and wash tubs should be located as near the windows as possible.

Water closets, baths, etc. should not be placed too near windows in cold climates, because there is always a cold down draft near a window, and persons using these fixtures are liable to catch cold by being in contact with the draft while undressed.

Hot-air registers should not be permitted in the floor immediately in front of a water closet, because a current of hot air (which usually cannot be entirely stopped) is disagreeable to the person using the closet.

The fixtures should all be located with a view to the general convenience of the parties who will use them.

Thus, the cook's sink should be placed convenient to the kitchen range, yet far enough away to be unaffected by heat radiated from the range or from the boiler.

The dish-washing, or *scullery sink*, should be placed convenient to the dining room and kitchen.

The *laundry tubs* should be convenient to the back yard, or drying room, as the case may be. If located in basements, they should be placed in front of the windows, so that the best light possible may be obtained upon the work. The butler's pantry sink should be conveniently near the dining room, preferably between it and the kitchen.

The water closets, baths, and wash basins should be convenient to the bedrooms. If wash basins are to be placed in bedrooms, care should be taken to place them as far away from the beds, yet as near to the light, as possible, and near the vertical waste stacks into which they will discharge, so that long branch waste pipes may be avoided.

Slop sinks should be placed at points convenient for drawing off water from bedroom urns, etc., and for receiving bedroom slops.

A water closet arranged for servants' use should be located on the ground or basement floor, because most of the servants' time is spent in the lower part of the building. No fixtures should be located in dark or unventilated closets, particularly those in the center of a building, because odors from the closets will diffuse throughout the building and become a dangerous nuisance.

Fixtures on the several floors of tall buildings should be arranged over one another as much as possible, and clustered in vertical rows, so that short branch waste pipes will be required to connect them to a soil-pipe stack common to them all.

Fixtures should not be set over parlors, dining rooms, libraries, or other rooms having valuable furnishings or decorated ceilings, for a leak is liable to do great damage; rather, they should be located over kitchens, sculleries,

pantries, closets, etc., so that a leak will do little damage. The soil and waste pipe stacks should not be run in walls adjoining living rooms, because the sound of water falling down these pipes is disagreeable.

MATERIALS.

PIPES.

73. Pipes for the use of plumbers are made of many materials, including lead, lead with tin lining, block tin, brass, copper, wrought iron, wrought iron with lead lining, cast iron, fireclay, terra cotta, and wood.

The sizes and weights of lead pipe, tin-lined lead pipe, and pure block-tin pipe, are given in the following tables:

TABLE 1.

WEIGHT PER FOOT OF LEAD PIPE AND TIN-LINED LEAD PIPE.

Inside Diameter.	AAA Brooklyn.	AA Extra Strong.	A Strong.	B Medium.	C Light.	D Extra Light.	E Fountain.
In.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.
$\frac{3}{8}$	$1\frac{3}{4}$	$1\frac{1}{2}$	$1\frac{1}{4}$	1	$\frac{3}{4}$	$\frac{5}{8}$	$\frac{7}{16}$
$\frac{7}{16}$				1	$\frac{13}{16}$		
$\frac{1}{2}$	3	2	$1\frac{3}{4}$	$1\frac{1}{4}$	1	$\frac{3}{4}$	$\frac{9}{16}$
$\frac{5}{8}$	$3\frac{1}{2}$	$2\frac{3}{4}$	$2\frac{1}{2}$	2	$1\frac{1}{2}$	1	$\frac{3}{4}$
$\frac{3}{4}$	$4\frac{3}{4}$	$3\frac{1}{2}$	3	$2\frac{1}{4}$	$1\frac{3}{4}$	$1\frac{1}{4}$	1
1	6	$4\frac{3}{4}$	4	$3\frac{1}{4}$	$2\frac{1}{2}$	2	$1\frac{1}{2}$
$1\frac{1}{4}$	$6\frac{3}{4}$	$5\frac{3}{4}$	$4\frac{3}{4}$	$3\frac{3}{4}$	3	$2\frac{1}{2}$	2
$1\frac{1}{2}$	$8\frac{1}{2}$	$7\frac{1}{2}$	$6\frac{1}{2}$	5	$4\frac{1}{4}$	$3\frac{1}{2}$	3
$1\frac{3}{4}$	10	$8\frac{1}{2}$	7	6	5	4	
2	$11\frac{3}{4}$	9	8	7	6	$4\frac{3}{4}$	

Lead pipes of any size differing from the above weights are made to order.

TABLE 2.

LEAD TUBING.

$\frac{1}{16}$ in............$\frac{3}{4}$ oz. per ft.	$\frac{5}{32}$ in..........$2\frac{1}{4}$ oz. per ft.
$\frac{1}{8}$ in..........$1\frac{1}{4}$ oz. per ft.	$\frac{1}{4}$ in....5, 6, 8, 13 oz. per ft.

TABLE 3.

LEAD WASTE PIPE.

$1\frac{1}{2}$ in............2 lb. per ft.	4 in...5, 6, and 8 lb. per ft.
2 in.....3 and 4 lb. per ft.	$4\frac{1}{2}$ in......8 and 10 lb. per ft.
$2\frac{1}{2}$ in.....4 and 6 lb. per ft.	5 in..8, 10, and 12 lb. per ft.
3 in.....$4\frac{1}{2}$ and 5 lb. per ft.	6 in....12 lb. and up per ft.

TABLE 4.

PURE BLOCK TIN PIPE.

$\frac{1}{4}$ in. AAA.... 5 oz. per ft.	$\frac{5}{8}$ in. AA ...... 9 oz. per ft.
$\frac{1}{4}$ in. AA..... $3\frac{1}{2}$ oz. per ft.	$\frac{3}{4}$ in. AAA ....13 oz. per ft.
$\frac{1}{4}$ in .... 8 oz. per ft.	$\frac{3}{4}$ in. AA......11 oz. per ft.
$\frac{5}{16}$ in. AAA.... $6\frac{1}{2}$ oz. per ft.	1 in. AAA ....17 oz. per ft.
$\frac{5}{16}$ in. AA..... 4 oz. per ft.	1 in. AA......14 oz. per ft.
$\frac{3}{8}$ in. AAA.... 7 oz. per ft.	$1\frac{1}{4}$ in. AAA ....26 oz. per ft.
$\frac{3}{8}$ in. AA..... 4 oz. per ft.	$1\frac{1}{4}$ in. AA......18 oz. per ft.
$\frac{7}{16}$ in. AAA.... 7 oz. per ft.	$1\frac{1}{2}$ in. AAA ....36 oz. per ft.
$\frac{1}{2}$ in. AAA... 10 oz. per ft.	$1\frac{1}{2}$ in. AA......24 oz. per ft.
$\frac{1}{2}$ in. AA..... 6 oz. per ft.	2 in. AAA ....40 oz. per ft.
$\frac{1}{2}$ in .... 8 oz. per ft.	2 in. AA......26 oz. per ft.
$\frac{5}{8}$ in. AAA....11 oz. per ft.	

Any size or weight per foot is made to order.

The length of a coil of lead pipe from $\frac{1}{4}$ inch to 1 inch in diameter is about 60 feet, and the length of a bundle of lead pipe from $1\frac{1}{4}$ inches to 2 inches in diameter, about 36 feet.

On account of the large diameter and the thickness of the metal of lead waste pipe, this pipe is never coiled. It is generally made in 10-foot lengths and shipped as straight tubes.

74. Wrought-iron pipe is made either *black* or *galvanized*, and all American manufacturers conform the dimensions of the pipe to a standard list, as follows:

TABLE 5.

STANDARD DIMENSIONS OF WROUGHT-IRON PIPE.

Nominal Internal Diameter. Inches.	Actual Internal Diameter. Inches.	Actual External Diameter. Inches.	Thickness of Metal. Inches.	Internal Area. Square Inches.	Weight. Pounds per Lineal Foot.
$\frac{1}{8}$	0.270	0.405	.068	0.0572	0.243
$\frac{1}{4}$	0.364	0.540	.088	0.1041	0.422
$\frac{3}{8}$	0.494	0.675	.091	0.1916	0.561
$\frac{1}{2}$	0.623	0.840	.109	0.3048	0.845
$\frac{3}{4}$	0.824	1.050	.133	0.5333	1.126
1	1.048	1.315	.134	0.8627	1.670
$1\frac{1}{4}$	1.380	1.660	.140	1.4960	2.258
$1\frac{1}{2}$	1.610	1.900	.145	2.0380	2.694
2	2.067	2.375	.154	3.3550	3.667
$2\frac{1}{2}$	2.468	2.875	.204	4.7830	5.773
3	3.067	3.500	.217	7.3880	7.547
$3\frac{1}{2}$	3.548	4.000	.226	9.8870	9.055
4	4.026	4.500	.237	12.7300	10.728
$4\frac{1}{2}$	4.508	5.000	.246	15.9390	12.492
5	5.045	5.563	.259	19.9900	14.564
6	6.065	6.625	.280	28.8890	18.767

Wrought-iron pipes are made in lengths from about 15 to 20 feet.

All wrought-iron pipe which is $1\frac{1}{4}$ inches or less in diameter is **butt welded**; that is, the edges are joined face to face. All sizes above $1\frac{1}{4}$ inches are **lap welded**, the edges being lapped over each other.

All butt-welded pipe is tested at the mills to a pressure of 300 pounds per square inch, and lap-welded pipe is similarly tested to 500 pounds pressure per square inch.

Wrought-iron pipes having a greater thickness of metal

than those above are made, and are known as *extra strong* and *double extra strong.* The extra thickness of metal reduces the bore of the pipe, the outside diameter of each nominal size is never changed. Thus, all grades of pipe will connect properly with standard fittings.

75. Tubes of brass or copper are made of all diameters and thicknesses. The size by which these tubes are designated is always the outside diameter, and the thickness of the metal must always be specified, in order to secure tubing which is suitable for the purpose in view.

Brass and copper tubes are made by two methods, and are accordingly designated as *seamless drawn,* or *brazed* tubing.

76. Seamless drawn tubing is made from a solid block of metal without a joint, and is much superior in strength to brazed tubing. **Brazed tubing** is similar in structure to butt-welded wrought-iron pipe, except that the joint is secured by brazing.

Brass tubing is also made in sizes which correspond in external diameter with the sizes of wrought-iron pipe, in order that it may be screwed into the same fittings that are used for wrought-iron pipe. Tubing of these sizes should always be designated as *iron pipe sizes.*

77. Wooden pipes are usually made from solid square timber. The bore is made by an auger, which is forced throughout the length of the piece. Another variety is made by winding a flexible wooden strip or ribbon upon a mandrel spirally in such a manner that the layers overlap one another and then securing them together with cement. It is made of all diameters and of all lengths up to 20 feet.

78. Cast-iron pipes for plumbers' use are made with a socket on one end and a spigot on the other. They are made in two grades, the **standard** and **extra heavy,** the latter having the greater thickness of metal. These pipes are made 5 feet long, exclusive of the socket, and may be had from 2 to 12 inches inside diameter. They are sold by

the lineal foot. Pipes having a socket on each end, called **double hub pipe,** are sold by the piece.

The above cast-iron pipes are used chiefly for the drainage of buildings.

Cast-iron pipes used for conveying water under pressure, such, for example, as pipes from a reservoir to a building, are much heavier and longer than those for drainage purposes. Cast-iron pipes may be had either **plain,** i. e., as they come from the mold, or **coated** with some particular material, such as asphaltum. In ordering this kind of pipe, it should be stated whether *plain* or *coated* is wanted.

79. Earthenware drain pipes are of various qualities as to texture, varying from a porous material like that of common red brick (sometimes called **terra cotta**) to a hard and compact material which is glazed to make it water-tight, called **salt-glazed** or **vitrified earthen** pipe. The latter class is made in 2 and 3 foot lengths, and has a socket on one end. The sizes usually kept in stock by dealers are 3, 4, 5, 6, 7, and 8 inch inside diameters.

CHOICE OF MATERIALS.

80. Globe valves and **globe checks** retard the flow of water too much, and, therefore, should not be used for low-pressure work, nor where a loss of pressure would be objectionable. **Gate valves,** or **plug cocks,** should be used instead, as they afford a freer passage for the liquid.

81. Plug, or **ground key, bibbs** are not suitable for water which carries fine sand or grit in suspension. The fine particles of sand will get in between the plug and the socket and cut grooves, thus forming small waterways and causing the cock to leak. Neither are they very suitable for high pressure, if much used, because of the unavoidable wear and tear on the parts whose seats have been ground, which under a high pressure will soon leak. They are, however, suitable for low pressure if the water is free from grit.

82. Compression cocks are suitable for faucets only, and should not be used as cut-off or controlling valves.

For faucets, compression bibbs have the advantage over plug cocks of closing slowly, and thus avoiding destructive shocks upon the piping. Also, if they become leaky, they can be readily supplied with a new valve disk; while, if a plug cock becomes leaky, it must be reground.

83. Hot-water connections may be made of lead, brass, copper, or galvanized iron. Plain iron is unsuitable. The choice will depend upon the pressure and upon the appearance desired; also, upon the character of the water, and its action upon the metal. In all cases where the water corrodes the metals named, pipes must be used which have an interior coating of glass or porcelain or are lined with pure block tin.

Brass tubing has these advantages: It will not corrode to any appreciable extent in pure water, and it will not sag in consequence of heat, as lead will do.

For carrying cold water, galvanized-iron pipe is generally used. It will endure the corrosive action of moist earth better than lead.

To secure easy curves and to avoid a multiplicity of sharp turns resulting from the use of elbows, **T**'s, or other iron pipe fittings in a building, the iron supply pipes may be continued to the fixtures with lead pipe which can be easily bent to fit any position.

In cases where it is known that the water will not corrode either lead or brass, the cold water may be conducted through lead pipe, and the hot water through brass.

Lead is unsuitable for underground pipes, because all soils corrode it externally and gradually destroy it.

Ale, beer, and other liquors should be conveyed in block-tin or tin-lined pipes.

84. Lead pipe is very smooth on the inside, and offers the least resistance to the flow of water. It is easily bent to suit any situation, and easy curves are readily made. It

is not suited to high pressures because of its small tensile strength.

Lead pipe varies greatly in quality. The pure lead is soft and pliable, and is particularly adapted for waste piping because it will stretch more equally, and will not tear or crack as quickly as a harder and more impure lead would while being worked into bends, etc. The hardness varies according to the kind and quantity of metals mixed with it. A hard, tenacious lead will stand more tensile strain than a softer lead. Therefore, no reliable estimate can be formed of the actual strength of lead pipe. It will bend under pressure without breaking, and is, therefore, desirable for connections to fixtures that are liable to change their position, in consequence of the settling or rocking of the building.

85. Brass and copper tubing are smooth inside, and are made of any thickness. They are best for heavy pressures of 60 pounds per square inch or more. Below that pressure lead may be used.

86. Galvanized-iron pipe is suitable for the heaviest pressures, but it must be put together with screw joints. The short bends and sharp angles, incident to this mode of connection, cause much friction, and impede the flow of water.

87. Plain, or black, wrought-iron pipe is subject to the same drawbacks, and it also rusts rapidly; it is very liable to clog by rusting internally.

88. Soil pipes should be made of cast iron not less than $\frac{1}{8}$ inch thick for diameters of 4 inches or less, nor less than $\frac{5}{32}$ inch thick for larger sizes.

For buildings under 65 feet in height, the *standard* grade is sometimes used, but in buildings higher than 65 feet, *extra heavy* soil pipes should be used. We recommend the exclusive use of extra heavy soil pipe and condemn standard cast-iron soil pipe as being unsuitable for house drainage work.

89. Wrought-iron pipe, put together with screw joints, is coming into use in some quarters, but it is still regarded as problematical. It appears to have some advantages.

When once made tight, it will remain so. The number of joints is much less. In some situations, screwed joints can be made where socket joints cannot be calked.

Wrought-iron pipe is very rigid; it is able to stand upon an independent base, and can thus be detached from the walls of the building. Its expansion and contraction due to changes in temperature is somewhat more than that of cast-iron pipe.

All soil or vent pipes of cast or wrought iron should be coated outside and inside with hot asphaltum. This should be done at the mills, by the maker. The fittings for soil, vent, or drain pipes, of cast or wrought iron, should always be *flush fittings*, so that the bore of the pipe shall be uniform, without enlargements or pockets.

90. Lead, as a material for soil or drain pipes, is rapidly going out of use. The chief virtue of lead pipe is the smoothness of its interior surface, which enables waste matter to flow through it very easily. Lead pipe will not corrode internally to a serious extent if it be well ventilated. Nearly all varieties of soil or earth will corrode lead pipe externally, therefore, it should not be used for underground drains. It should not be enclosed by cement or mortar where it passes through a wall without first being wrapped with tarred paper or other rot-proof material.

Lead soil pipes should not be less that $\frac{1}{8}$ inch thick. Steam rapidly destroys lead soil and waste pipes, and plumbing fixtures using hot water should not discharge into them. The alternation of hot and cold water will cause the lead to crack at the weakest point, usually at the supports.

If steam or very hot liquids are to be admitted to a drain, the pipe should be of wrought iron with screwed joints. The alternate expansion and contraction will strain and eventually destroy the calking in hub and spigot joints of cast-iron pipe.

91. Earthen or **vitrified** pipes are suitable for underground drains only, and even for that use are inferior to the cast-iron pipes. They should never be used inside of a building, nor in any situation where the leakage from them can

do any damage. They should not be used in the neighborhood of wells or cisterns, because they are so liable to crack and leak, and thus pollute the water in the soil for a considerable distance. They should not be laid in new or *made* ground, as this will settle with heavy rainfalls and the pipes will break. The pipes being so short, the number of joints is greater than of any other kind of pipe. Plain earthen pipes should only be used to drain wet ground. The vitrified or salt-glazed pipe should be chosen to convey sewage.

INSPECTION OF MATERIALS.

92. All materials should be inspected when received and before accepting them.

Black sheet iron should be examined for flaws or holes on its surface, for equality of thickness, and as to its liability to crack if bent sharply either with or across the grain.

93. **Galvanized sheet iron** should be examined for the same defects as black sheet iron. The zinc coating may be tested by bending the iron at a temperature of about 60° or 70° F. If the zinc adheres properly to the iron, it will not scale or peel off.

94. **Sheet copper, sheet lead,** and **sheet zinc** are generally accepted as they are placed upon the market.

95. **Lead pipe** should be soft and pliable. Examine for kinks, bruises, and punctures, caused by rough handling during shipment. In other respects, it is usually placed on the market in good condition and requires no further inspection.

96. **Tin-lined lead pipe** should have its interior surface examined, if possible, to see if it *is* tin lined. Shave off the end of the pipe square and clean, and ascertain the thickness of the tin lining by breathing on the highly polished end. The breath will discolor the surface of the lead with a thin blue coating, and the tin will remain bright. The thickness of the tin lining will thus become visible.

97. **Block-tin pipe,** like lead pipe, is generally accepted as reliable in the form placed upon the market. Pure block

tin may be detected by a peculiar crackling noise it makes when being bent at ordinary temperatures.

98. **Seamless brass tubing** should have an equal thickness all around, and should be slightly annealed to prevent its being too brittle for working.

99. In **brazed brass** and **copper** tubing, the brazed seam should be examined carefully. It should be uniformly loaded with hard solder and thoroughly *sweated.* If possible, examine both the inside and outside of the seam. The best and strongest form of brazed seam is *dovetailed.* Lap or butt brazed seams are liable to warp in the process of brazing, and are not very strong.

100. **Galvanized-iron pipe** placed upon the market is usually accepted as good. Sometimes, however, it is partly choked by the zinc, used to galvanize it, clogging in lumps. This may be detected by rolling a marble a size smaller than the pipe through its entire length, or, if possible, by looking through it. The quality of the galvanizing may be observed by bending the pipe at an ordinary temperature, to an easy bend. If the galvanizing is good, it will remain intact. Galvanized-iron pipes are liable to be quite brittle, but this brittleness does not seem to affect the durability of the pipe. The ductility of galvanized-iron pipes is less than that of black iron, and sometimes is so low that if the pipe is bent successfully, it cannot be bent back without breaking.

101. In **wrought-iron pipe** (**black**) the welded seam which runs the whole length of the pipe should be examined. A good welded seam is scarcely visible, and the pipe should have a smooth external and internal surface. The pipes should be straight and the threads should be cut clean.

102. **Cast-iron drain** and **soil pipes** should be examined for sand holes in the metal or splits in the pipe. A fracture can be detected by tapping the pipe with a chisel or small hammer. If the pipe is sound, it will ring clearly when struck, and if cracked, it will give a dull, harsh sound.

Sometimes the *core* will shift when a pipe is being cast.

particularly if the pipe is cast horizontally, in which case the core is liable to rise. This will cause the metal to be thicker at the bottom than at the top of the pipe. Irregularities in thickness can be detected by irregularities of the sound when rapped with a hammer at various points.

103. **Earthen drain pipes** are liable to warp and twist in firing. They should be examined for an equal caliber, smooth, glazed internal and external surface, and particularly for cracks around the back of the socket and irregularities within the socket. Pipes having broken or crooked sockets should be rejected.

104. **Fittings** for **wrought-iron** and **brass pipe** should be inspected for sand holes and flaws, and it should be seen that the screw threads are deep and full. All screwed fittings should be reinforced with a heavy bead cast on the edge.

105. **Fittings for cast-iron drain pipes** should be examined for sand holes, splits, and other flaws, and for lumps and other obstructions to the free flow of sewage through them.

106. **Fittings** for **earthen pipe** should be examined for irregularities in cross-section, or caliber, cracks, protruding pieces of salt glaze, abrupt turns, etc. The sockets should be examined to see that they are round and of proper depth.

HOUSE DRAINAGE.

SEWAGE AND SEWER GAS.

107. **Sewage** is composed of water mixed with kitchen slops, grease, soap, urine, washings from stables and slaughter-houses, rags, leaves, paper, human excreta, etc. The animal and vegetable matters in it rapidly decompose and generate noxious gases, and the combination of these is called **sewer gas.** These gases are poisonous, and will inevitably produce sickness if they escape into a dwelling, or if they are breathed in any considerable quantity for even a few minutes.

An exceedingly dangerous feature of the air contained in sewers is that it is liable to be loaded with putrefactive germs,

which will develop typhoid fever, scarlet fever, and diphtheria, if they find a lodgment in the human breath or food.

A small leak of sewer gas into a house may cause much sickness that will probably be ascribed to other causes. Many people will endure a small amount of bad odor rather than incur the expense of sending for a plumber, and are unwilling to believe that a small defect in the drainage can do so much mischief. But the architect must protect people against their own ignorance and cupidity in this matter.

It is clear, from the nature of sewer gas, that traps and vents upon the drains are not luxuries, but are absolutely necessary to the health of the community.

TRAPS.

108. A **trap** is a device which allows the free passage through it of liquids and such solid matter as the liquid may carry with it, but which prevents the passage of air or gas in either direction.

The simplest form of trap is shown in Fig. 33. It consists of a downward loop in a horizontal pipe. The loop is

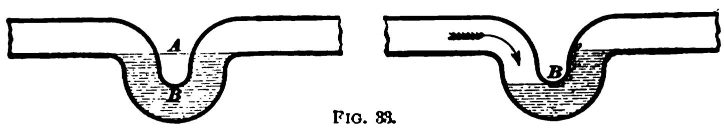


FIG. 33.

filled with water while the pipe at each side of it may be empty. Whenever water is run through the pipe, enough will be retained to fill the bend and prevent air or gas at atmospheric pressure from passing. If the air has sufficient pressure it may force the water down upon one side of the bend and up upon the other until the air can escape past the bend at B, and bubble upward through the water. The difference between the level of the water when quiet as at A, and the point B, is called the **seal** of the trap.

109. Fig. 33 exhibits the principle of the class called **round-pipe,** or **Du Bois** traps. The usual forms of round pipe traps are shown in Fig. 34.

A is known as an **S** trap. It is used chiefly under fixtures where the waste pipe descends to the floor.

B is a half **S** or **P** trap. It is used chiefly to join fixtures to a horizontal waste-pipe branch.

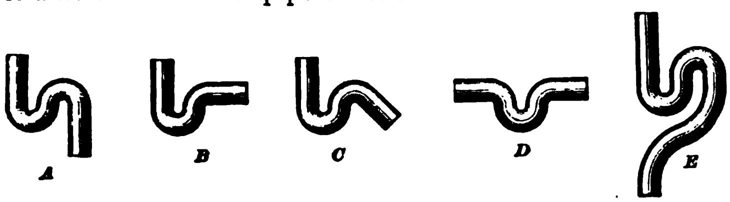


FIG. 34.

C is a three-quarter **S** trap. It is used chiefly to join fixtures to a **Y** branch in a soil pipe where the distance between the trap and the branch is short.

D is a lying or running trap. It can only be used on a horizontal waste pipe. It is often used as a bath trap, being placed under the floor.

E is a hunchback trap. This form is used on a vertical pipe where it is desired to have the inlet and outlet in the same straight line. It is not used as much in plumbing as the other forms.

110. In Fig. 35 is shown a **bottle** trap. This trap is only used under fixtures, such as sinks, baths, basins, or wash tubs, never under water closets. The inlet pipe *A* is

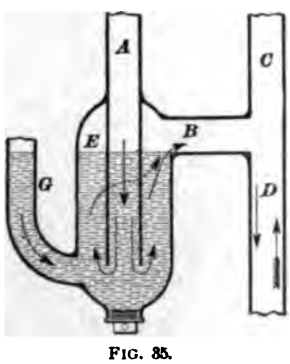


FIG. 35.

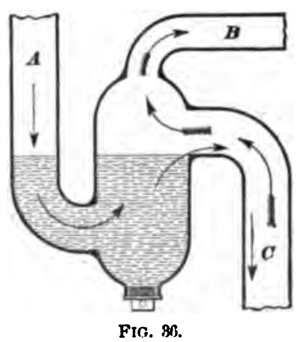


FIG. 36.

attached to the fixture, and the outlet pipe *B* joins the waste pipe *D*, of which the part *C* forms the back-vent. *G* is an

overflow pipe. It is next to impossible to unseal this form of trap, although some of the seal may be lost by siphonage. Its chief objections are that filth is liable to accumulate in the bottom of the trap and grease upon the top of the water and in the chamber E, and that the water cannot be completely renewed every time the fixture is used.

111. In Fig. 36 is shown a modification of Fig. 35. It is more direct in action than Fig. 35, and is more easily unsealed. It, however, overcomes the danger of drain air entering the building through unseen holes in its interior, as would occur if the tube A in Fig. 35 were corroded within the chamber E. Care must be taken when attaching an overflow pipe, for instance from a wash basin to any form of trap, particularly to those of the pot or bottle formation, to have the proper seal.

In Fig. 36 the trap receives waste water from the fixtures by the pipe A. B is the back-vent pipe, and C the waste pipe. The arrows with feathers show the direction of the natural air currents in the drainage system.

112. In Fig. 37 is shown a **ball** trap, in which a trap is combined with a check-valve. The ball valve c prevents the return of either liquid or gas, and the liquid around the ball keeps the seat gas-tight.

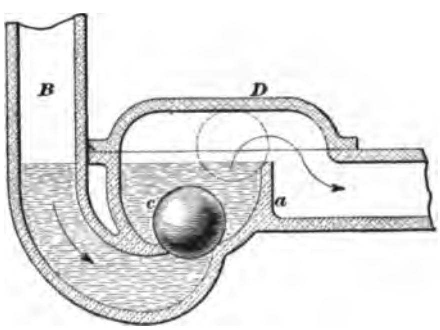


FIG. 37.

The specific gravity of the ball is but slightly greater than that of water, so that a very slight head of water in B will raise the ball. This trap is particularly suitable for clean-water fixtures, such as basins or baths, which are liable to remain unused a sufficient length of time to permit the water in the trap to become evaporated and its seal consequently lost. In such a case, the ball will form a nearly

gas-tight joint with its seat and prevent the passage of drain air to the building.

This trap, and all other traps having the water way restricted by mechanical appliance, such as check-valves, are liable to chokage by accumulating hair, small pieces of rags, sponges, and even matches.

The position of the ball when water passes through the trap is shown by dotted lines. It cannot enter the trap outlet pipe, as the space between the lip *a* and the handhole cover *D* is too small.

113. A **bell** trap is shown in Fig. 38. In it the seal is formed by the bell *a* which is suspended from the strainer *b*,

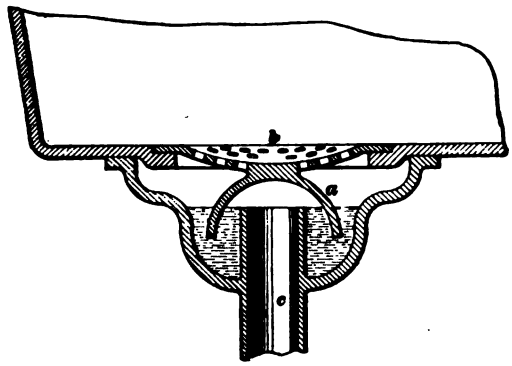


FIG. 38.

dipping into a small pool of water formed by the waste outlet *c* projecting into the trap casting. The chief objections to the bell trap are:

1. It soon becomes choked by sediment lodging in the bottom, which cannot be removed without lifting off the bell. This, for the time being, permits open communication between the drains and the building.

2. It is easily siphoned.

3. It is quickly evaporated if not used.

In fact, the bell trap has no redeeming features, and should be abolished in house-drainage systems.

114. General Remarks.—The *requirements of a good trap* are: (1) that it shall entirely and effectually prevent the

passage of any air or gas from the waste pipe backwards into the house; (2) that it shall be so constructed that it can be readily cleaned; (3) it should clean itself on all ordinary occasions.

Round-pipe traps are usually of the same diameter throughout, and they freely pass nearly everything that can get into them, but they are very liable to become useless through the removal of the water which seals them, by siphonage or evaporation.

The *bottle* trap can seldom be emptied or siphoned, and as it contains a large volume of water, it will withstand evaporation for a longer time than other traps. It will clog easier than a round-pipe trap, but is quite as easily cleaned by removing the screw plug, which is provided for that purpose. The same depth of seal forms a more effectual barrier against the back flow of gas in a bottle trap than in a round-pipe trap.

Traps for outdoor service, to receive surface water from courts, areas, roofs, etc., should have a deep seal, from 8 inches to 1 foot, according to the warmth and length of the dry seasons.

Check-valves should not be used in place of traps, because they are very liable to be prevented from closing properly by the lodgment of refuse, such as strings, rags, paper, etc., between the valve and its seat.

All traps should have a cleaning hole. The screw plug which is used to close the hole should be of such shape and size that a wrench can be applied to it firmly and safely. Large traps, such as used for drains, should have a hand-hole and a suitable cover. These plugs or covers must always be made both water and gas tight.

A separate trap should be placed under each bath tub, wash basin, sink, water closet, or urinal, and one trap should be attached to each set of laundry tubs. Traps should be set as close to the fixtures as possible. A trap should be placed in each main drain so as to disconnect the house pipes from the sewer. A trap should not be placed at any point where it will check the free circulation of air through the drainage system.

115. To prevent the back flow of water from sewers, etc. into basements or areas, a **back-water** trap should be employed. This allows the water to pass outward freely, but allows none to return.

A common form of back-water trap is shown in Fig. 39. This is used chiefly to drain water from the basement floors, etc., where there is danger of water backing up from the sewers. The valve is composed of a hollow copper float *A*, encircled by a soft rubber ring *B*. A rest, or stop, *E* for the float is attached to the brass valve seat *G* by four arms.

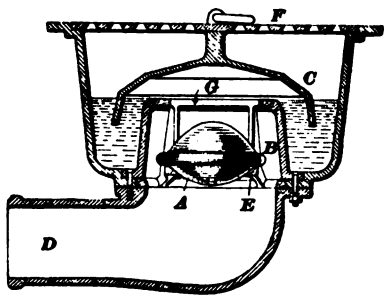


FIG. 39.

These arms also act as guides to lead the valve to its seat when the sewage water rises in the drain pipe *D*, and buoys up the valve. When the water falls in *D*, the float will fall from its seat and descend with the receding water until it reaches its stop, as shown, when it will be again open for surface water. A bell-shaped casting *C*, suspended from the perforated cover *F*, dips into water and forms a seal to prevent drain air from entering the building.

116. Refrigerators should have a trap on the waste pipe. The object of the trap is to allow the waste water to pass out, and to prevent the cold air from escaping also. The cold air is heavier than the air at ordinary temperatures, and it settles at the bottom of the chamber. If there is any hole open, the cold air will flow out very much as water would, and the result is a waste of ice. The trap also prevents the entrance of bad air or dust. Cooling rooms for butter and cold storage must be carefully guarded in this respect.

Ample facilities for cleaning the traps must always be provided, because they frequently choke with the sawdust which accompanies the ice.

The waste pipe should not be directly connected to a drain, or sewer pipe, but should discharge into some clean place where it can be watched, and where there is no bad air. The utmost cleanliness must be preserved at all points about refrigerators or cold-storage rooms.

117. Rain-water leaders, if connected to the drains, must be provided with traps, having a seal so deep that the water in them will not evaporate sufficiently to unseal them during long spells of dry weather. These traps must be secured against frost. They are usually placed in the cellars.

GREASE INTERCEPTERS AND TRAPS.

118. Grease is very troublesome, because it is liquid and runs out of the sink readily while accompanied by hot water; but as soon as it encounters the cold surface of the waste or drain pipe, it solidifies and adheres to the pipe. The caliber of the pipe is thus reduced, and it will eventually be choked by the grease.

An ordinary variety of **grease intercepter** and **trap** combined is shown in Fig. 40. *C* is the waste pipe from the sink, *B* is the pipe leading to the drain, and *A* is a fresh-air inlet. The cover *D* should be large enough to readily permit the inside of the trap to be cleaned, and should be secured in position. The grease accumulates in a layer at *G*, and if allowed to become cold, will solidify into a cake, which can easily be removed.

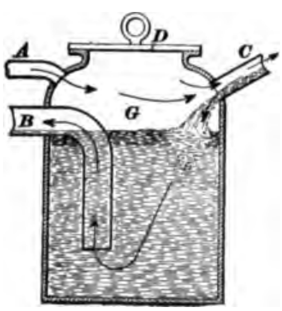


FIG. 40.

This form of grease trap is mostly used for intercepting grease from kitchen sinks in large country buildings. As the trap must be large, in order to prevent the grease from entering the outlet *B*, it is usually placed underground as near the sink as possible.

119. A **chilling grease trap** is shown in Fig. 41. *B* is the waste pipe from the sink, and *D* is the pipe leading to the drain. *F* is the vent pipe, and *K* is a local vent, or air-relief, pipe. The contents of the trap are chilled by means of a jacket *A* through which cold water is made to circulate.

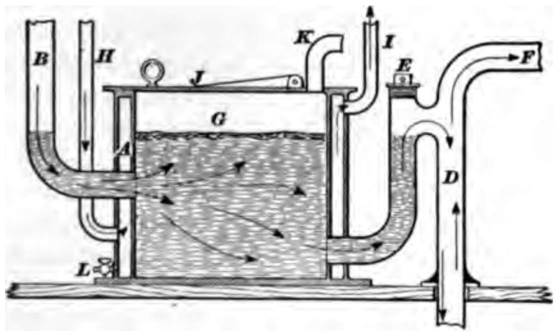


FIG. 41.

Commonly, the cold-water supply to the kitchen boiler is used for this purpose, the water entering the trap through *H* and passing to the boiler through *I*. *J* is a close-fitting hinged cover. The grease chills into a cake at *G* and is removed by opening the cover.

The separation of the grease will be more perfect in this trap than in the one shown in Fig. 40, because the layer of grease is not disturbed by the water in entering or in leaving the trap. In Fig. 40 the entering water passes through the layer of grease and is liable to carry some of it along over into the waste pipe. A trap screw *E* is attached for access to the trap outlet. A petcock *L* is screwed into the water-jacket to drain it when required.

VENTS AND SIPHONAGE.

120. The water which seals a trap is very likely to be drawn out by the suction of the water which passes down the waste pipe, unless some means be used to destroy the suction. The waste water should always be driven through the

trap by hydraulic pressure, instead of being pulled through by suction. Suction can be entirely prevented by attaching an **air** or **vent** pipe, as shown at *a* in Fig. 42. The effect of siphonage is shown in Fig. 43. The suction will continue until the level of the flowing water falls below the tongue of the trap at *a* when air will enter and stop the suction. The water between *a* and *c* still has considerable momentum, and some of it will pass over *c*, but the remainder will fall back into the lower bend. This quantity, however, is too small to fill the bend, consequently, an opening is left which permits the back flow of sewer gas, as shown by the arrow.

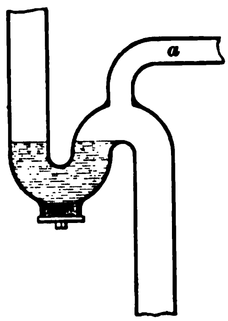


FIG. 42.

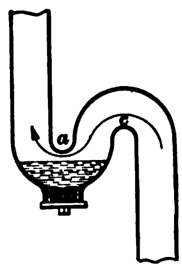


FIG. 43.

121. A **local vent** is a device for creating an outward current of air, for the purpose of carrying away the offensive odors which arise in the bowl of a water closet, urinal, or other fixture. It is attached between the fixture and the trap, or to the fixture itself.

Local vents should never be connected to the main ventilating stack, nor to any trap or soil-pipe vent, because if they are so connected, the gases from the soil pipe will be driven back into the house during stormy or windy weather. To secure a current of air that will be effective, the local vent pipe should be carried upwards, inside of a chimney flue which is in constant use; or the pipe may be run outside, but close against the flue so that the heat of the chimney will help to create a draft. The outlet of the pipe should have a cowl, to prevent the wind from blowing downwards in it. A local vent is useless without a good draft. The pipe should not be less than 2 inches in diameter for one closet, or urinal, 3 inches for two or three closets, or urinals, and 4 inches in

diameter for four or five closets, or urinals, if its length is not over 50 feet. It should be larger if the pipe is much longer or if it contains a number of bends.

WASTE PIPES.

122. Waste pipes are those pipes which convey waste water from any or all of the fixtures in a building except the water closets. If their length exceeds 4 or 5 feet, they are usually made of cast iron. A general custom in the United States is to make all stacks or vertical lines of pipes of cast iron, with spigot and socket joints.

The branch pipes through which the fixtures discharge into the stack are made of lead, if short. If more than 5 feet in length, and without too many changes in direction, an iron-pipe branch is generally carried to a point suitable for a lead-pipe connection to the fixture. The reason why lead waste-pipe connections are generally made to the fixtures is because the lead can be bent to suit any position, and forms a pliable connection which will not break the fixture owing to a small settlement of the pipes or building. But it must be thoroughly supported to prevent it from sagging. The pipe should be inclined towards the stack to secure a rapid flow of water. The **Y** branch of the stack should be located as low down as practicable, and the waste pipe may be run between the floorbeams.

123. The waste pipes from baths and basins should be connected directly to the soil-pipe stack, and should not be connected to the water-closet branch.

Waste pipes of lead should not be wiped or connected at right angles, but always at a larger angle, which will favor the passage of matter towards the outlet.

Care must be taken that the water which is being discharged from one waste pipe does not back up into some other pipe, because it will form deposits in, and choke up, the other pipe.

The waste pipes from safes should not be connected to a soil or vent stack. They should discharge openly at some conspicuous place where the least indication of a leak will be quickly made apparent.

The waste pipe from a refrigerator should not, under any circumstances, be connected to a soil or vent pipe, but should discharge at some clean place.

The overflow from a house tank, or cistern, should not be discharged into a drain, or soil, pipe, but should discharge openly in a place where the overflow will be seen.

Urinal waste pipes should be as short as possible. They should be well supplied with screw-caps, to afford easy access to the pipe for cleaning-out purposes, as a thick slime accumulates in such pipes.

124. The proper **sizes of waste pipes** for various uses are as follows:

Bath waste, 1½ inches to 2 inches in diameter.

Basin waste, 1¼ inches to 1½ inches in diameter.

Urinal waste, 1¼ inches to 2 inches in diameter.

Wash tubs, 1½ inches branch and 2 inches trap for three tubs, the trap taking one tub.

Sink waste, 1½ inches to 2 inches in diameter.

Pantry sink waste, 1½ inches in diameter.

Safe waste, 1 inch to 1½ inches in diameter.

Water-closet trap, 3¼ inches to 3½ inches in diameter.

Soil-pipe stack, 4 inches or 5 inches in diameter.

Branch to closet from soil-pipe stack, 4 inches in diameter.

Sink and tub stack, 2 inches to 3 inches in diameter.

SOIL AND VENT PIPES.

125. Soil and vent pipes should run vertically if practicable, and if they must be run otherwise, they should be inclined not less than 1 foot in 40 feet. All bends and curves should be made of large radius. Where an **offset** has to be made in a soil or vent pipe, it is advisable to use

two **obtuse angle** or **eighth bends,** *B*, *B*, as shown in Fig. 44. Right angle or **quarter bends,** as at *A*, should not be used for this purpose.

All branches to waste pipes and connections to the main drains should be made with **Y branches,** as shown in Fig. 45, instead of branches at right angles.

The **Y** branch *A* should be inclined in the direction

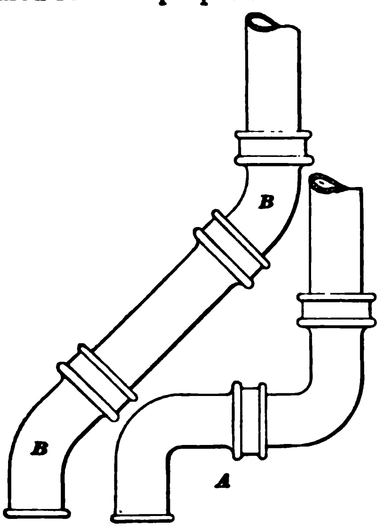


FIG. 44.

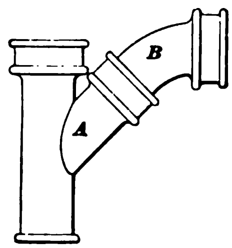


FIG. 45.

of the flow, that is, downwards towards a soil pipe, and upwards towards a vent pipe. By inserting an eighth bend *B* into the **Y** branch, one pipe can be connected to another at right angles in a proper manner.

126. All soil pipes should extend through and above the roof. The diameter of the pipe must be increased before it passes through the roof, because the warm air and vapor which rise in it will be condensed, and in cold weather the outdoor end of the pipe will become lined with ice. The formation of ice will continue until the mouth of the pipe may be choked. By enlarging the pipe, the time required to choke it is greatly prolonged. Thus a 4-inch stack should be increased to 5 inches diameter at the roof, as shown in Fig. 46. The hub of the 5-inch piece *B* should extend above the roof to the extent shown or slightly lower. The opening through the roof should be made water-tight by means of the

flashing *F* of 6-pound sheet lead. This should be extended upwards under the shingles or slates *A* and be securely nailed to the roof boards. The hole for the pipe *C* should be flanged downwards into the hub *B*, so that when the joint is calked with oakum and lead, a perfectly water-tight joint will be made with the flashing.

127. All branch pipes should be ventilated. This is usually accomplished by attaching a **back-vent pipe** to the

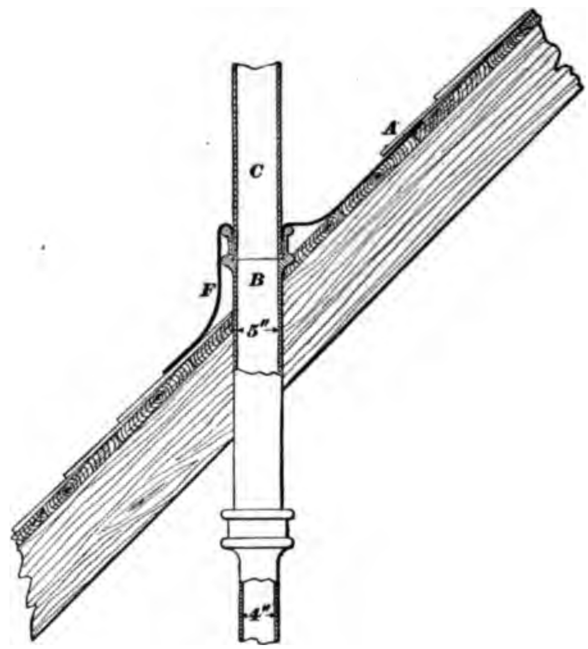


FIG. 46.

crown of each fixture. It will relieve the pipe from accumulations of foul gas, secure a steady current of fresh air through the branch pipe, and prevent the sealing water from being sucked out of the traps by siphonage.

The separate back-vent pipes should be connected to one vent stack unless the horizontal distance to be traveled is so

great that a good draft cannot be secured. Local vents must not be connected to the vent stack. Rain-water leaders should not be used for vent pipes. Vent pipes must be connected to that side of the trap which is between the seal and the soil, or drain, pipe.

128. The proper mode of connecting the vent pipe is shown at *A*, Fig. 47. A common, but improper, **vent connection** is shown at *B* and *D* in the same figure. When a large volume of water enters the trap suddenly, it will drive up into the part *D*, and if it carries grease, soap, or refuse with it, it will be deposited in *D* as shown. After a time the vent will become choked and perhaps entirely closed. If the

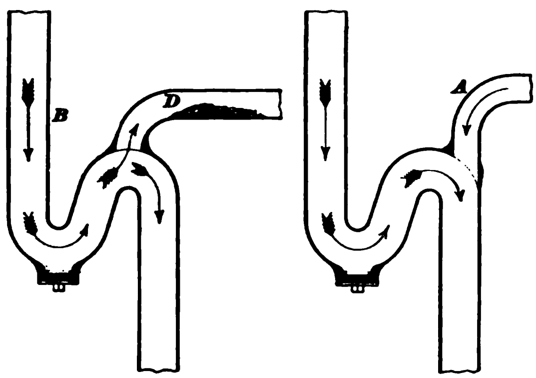


FIG. 47.

vent pipe be attached as shown at *A*, the current of water will tend to create a suction and a downward current in the vent pipe, which will prevent the deposit of any grease or refuse at that point.

129. The vent pipe should be attached to the stack at such a height that, in case the waste pipe becomes choked, the waste water cannot pass through the vent pipe into the stack without filling the fixture and thus giving notice to the householder that something is wrong. It also prevents an

overflow by the discharge of waste water from the floors above. This is illustrated in Fig. 48. The kitchen sink *A* is connected to the waste and vent pipe stacks *B* and *C*. The waste stack is choked at the point *D*, and waste water from the sinks above rise in the waste branch *E*, half fills the sink *A*, then discharges into the vent pipe *C*; thence into the drain, to which the vent stack is connected at its base. The cause of the chokage at *D* is presumably oakum, driven into the pipe by a careless workman, which accumulates falling solid bodies until the pipe is entirely closed. Tea leaves and coffee refuse make the chokage water-tight.

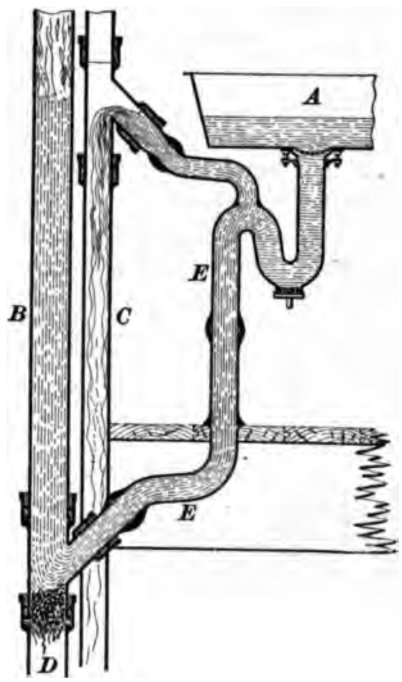


FIG. 48.

If the back-vent branches be too low, this dangerous state of affairs may go on unnoticed, until finally the system becomes so clogged that it will at last show itself somewhere.

DRAINS.

130. Drains should have a uniform **pitch** or fall throughout their length. The line of pipe must not have any part of it run on a level, nor should it be allowed to have any part of it sag below the general inclination, so that a pocket can be formed in which water will lie. The proper inclination or pitch to be given to drains varies with the diameter of the pipe, being greatest for the smallest diameter.

The inclination should be enough to give the water a velocity of about 275 feet per minute. A less velocity will fail to carry along the solids which usually accompany the water.

131. The *proper fall* for each size of pipe is given in the following table, 1 foot of fall being allowed for the length given under each diameter:

TABLE 6.

Diameter..........	2	3	4	5	6	7	8	9	10	inches.
Length to 1 ft. of fall	20	30	40	50	60	70	80	90	100	feet.

Thus, a pipe 3 inches in diameter should be laid with a minimum fall of 1 foot in 30 feet of length.

132. The *proper diameter* of the pipe to be used for a drain is a matter that requires careful consideration. The pipe should be large enough to carry off, within reasonable time, the largest quantity of water that will ever be turned into the drain; yet, it must not be so large that the ordinary flow of water will fail to float and carry along the refuse that ordinarily accompanies the water.

Thus, the quantity of water which would run properly in a 5-inch pipe would, if passed through a 9-inch pipe, be so shallow that it would not float and carry the refuse along. This may be seen by observing the difference in depth between the water in the 5-inch pipe, shown in section in Fig. 49, and the same quantity in the 9-inch pipe, shown in section in Fig. 50. In Fig. 49 the solids discharged from the water closets can easily be floated and carried along with the current without even touching the pipe. Since they do not

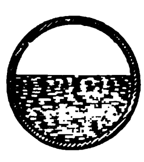


FIG. 49.

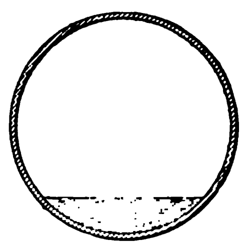


FIG. 50.

touch the pipe and are submerged in the center of the moving water, it follows that they must move forward as fast as the water which surrounds them. In the 9-inch pipe, however, with the same quantity of water, the solids will touch the pipe, because the water is not deep enough to properly float them. The adhesion of the solids to the pipe will create such a resistance to their movement that the water will soon flow ahead and leave them behind, where they will remain until another flush comes and moves them forward a little further.

133. The velocity with which water will flow through a pipe will depend upon the degree to which it fills the pipe. This is shown by the diagram, Fig. 51. If the level of the flowing water is at D, and the length of the line $D E$ is taken

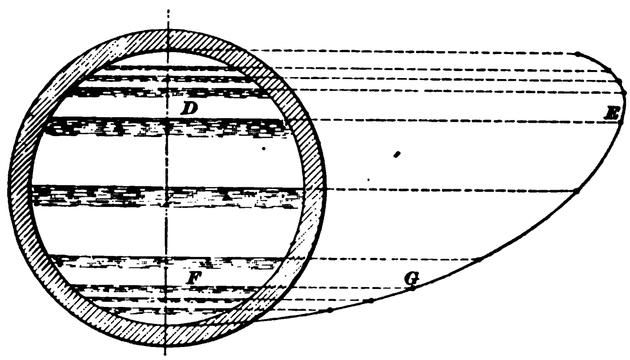


FIG. 51.

to represent the velocity of the current, then the velocity of a quantity of water which fills the pipe only to the level F will be represented by the line $F G$. The difference is largely due to the greater friction of the smaller stream, the proportion between the wet surface of the pipe and the quantity of the water being much greater at the level F than at the level D. It will be noticed that when the pipe is about three-fourths full the maximum velocity is attained.

A diameter of 4 inches is usually sufficient for a drain for an ordinary dwelling; if the rain pipes empty into it, a 5 or 6 inch pipe should be used.

134. Care should be taken to lay drain pipes in a straight line. If they are made of earthenware, every length of pipe should be cemented, thoroughly cleaned, and examined inside before proceeding with the next piece.

When laying earthenware pipe, care should be taken that no cement is left projecting inside the pipe as at *x*, Fig. 52.

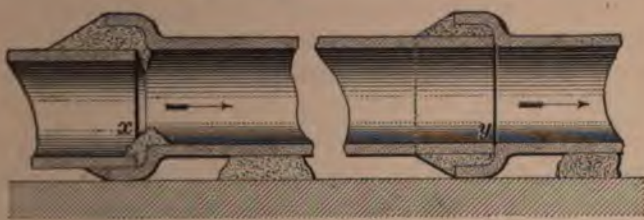


Fig. 52.

The inside surfaces of the pipe should lay flush and true as at *y*. All bends and curves should be of large radius. Right-angled branches and sharp turns should be avoided.

Drains should not pass under a dwelling if it can possibly be avoided. If the drain pipe passes through or under a foundation wall of a building, a liberal allowance must be made for the probable settlement of the wall. In new buildings, and upon made ground, the settlement is likely to be considerable.

135. Steam or very hot liquids should not be discharged into an ordinary drain. If there is much steam or hot liquids to be carried away, a special drain should be made for the purpose. They must never be discharged into a street sewer, unless the liquid is first cooled.

136. All drains should be provided with **inspection pieces** and **cleaning holes,** through which the interior of the pipe can be seen, and through which cleaning tools can be introduced. Care should be taken in locating these pieces or handholes, that sufficient room is provided around them to handle the cleaning tools.

Such an inspection piece is shown in Fig. 53. The cover

A is secured by bolts, and is made air-tight by a gasket *B*. These fixtures should be located at each bend in a main

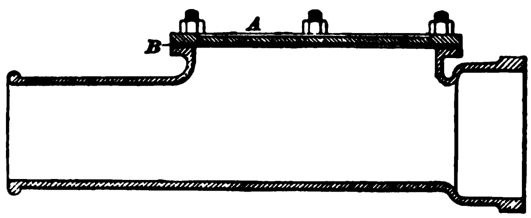


FIG. 53.

drain, so that every part of the drain may be examined with a lamp and mirror when desired. The inspection piece shown in Fig. 53 is particularly adapted for placing at regular intervals of 75 to 100 feet along a straight underground drain, in which case it would be built in a brick manhole about 3 feet long by 2 feet wide.

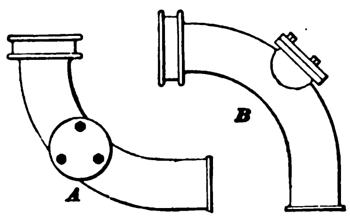


FIG. 54.

137. Two bends, with an inspection hole and covers, are shown in Fig. 54. *A* is suitable for joining two horizontal drains, while *B* is suitable for a vertical and horizontal junction.

138. Drains should be flushed periodically to wash them clean and remove all accumulations of filth. To do this properly, a large volume of water is necessary, and it should be released suddenly. The flow should be sufficient in volume to completely fill the bore of the pipe, and the head should be great enough to insure a swift and forcible current.

Automatic flushing tanks for this purpose are constructed to receive and store the water from the roofs, and sometimes the water from the wash bowls and bath tubs is stored in a tank of this kind. When the tank becomes full, it discharges itself in a strong, steady stream, thus effectually scouring the drain to which it is attached.

MAIN DISCONNECTING TRAPS.

139. The main disconnecting trap, or **main drain trap,** as it is sometimes called, is a very important detail in a house-drainage system. Its office is to prevent gases in the city sewers or cesspools from entering the house drains. These gases are usually considered to be more dangerous than those generated within a house-drainage system.

The requirements of a good main disconnecting trap are:

1. It should, under all conditions and at all times, maintain a perfect disconnection between the gases in the street sewers and those in the house drains.

2. It should, under all ordinary conditions, be self-cleansing, so that solid matter may not accumulate in it and evolve gases.

3. It should, in all cases, be accessible for cleaning-out purposes and for inspection, the handholes being maintained positively gas-tight, preferably by means of screwed joints (metal to metal), not by a bedding of putty.

140. In Fig. 55 is shown a trap so constructed that, when set properly, the inlet lip *e* is about 2 to 3 inches above the normal water-line of the trap. The liquid sewage, by falling into the *trap well*, that is, the space just over the water in the inlet side of the trap, will force any solid matter in the well down under the tongue and through the trap, as shown by the arrows.

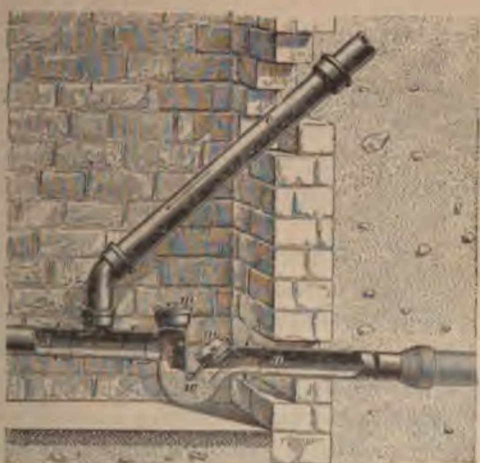


FIG. 55.

The space between the lip *e* and the water-line also provides

for a small head of water which is required to cause a flow through *a* to the sewer, and by so doing prevents water from backing in the house drain *b*. The solids carried by the water in *b* are easily deposited in the trap well, from which they are just as easily forced by the small cascade falling upon them, under the tongue and through the trap *w*.

In order to obtain easy access to *a* and *b*, or to the trap itself, the fresh-air inlet *c* is joined to a **T** branch, and a 4 or 5 inch brass trap screw, the socket of which forms a sleeve for calking, is secured into the hub of the trap, as at *m*. This gives access to the main house drain and trap well.

Another handhole, or **access plate**, is shown at *n*; this is for easy access to the pipe *a*. It is very essential that this handhole be hermetically sealed, because the pipe *a* will constantly be loaded with sewer gas, and if the plate should not be bedded tight, sewer gas will flow into the cellar unobserved. A screwed cap having metal-to-metal contact is preferable for closing the handhole *n*.

Care should be taken to allow a space all around the pipe where it passes through the wall, particularly over it, so that the wall may settle without touching the pipe. The iron sewer connection *a* is continued through the wall to a distance of 5 or 10 feet before it joins the fireclay pipe, so that if any slight leak should occur in the fireclay pipes or their joints, the leakage will not affect the building.

The fireclay sewer pipe should never, on any account, be continued into the cellar.

141. When a main disconnecting trap must necessarily be located outside of the building and underground, it is customary to build a brick **manhole** around it for ease of access. If the manhole is remote from windows, doors, etc., it is customary to provide it with a perforated cover so that the fresh air may easily enter. In such a case, the handhole on the trap inlet is left open and the manhole floor is cemented water-tight and made flush with the handhole.

A manhole should be at least 2 feet 6 inches in diameter at the base, the walls being built of brick and 8 inches thick.

It should be closed on top by a flag of pavement at least 3 inches thick, and the iron cover or grating, as the case may be, should be sunk flush into the stone. The opening in the stone should be at least 15 inches in diameter, or square, and the plate which covers it should have a 1-inch bearing.

FRESH-AIR CIRCULATION.

142. All of the drains, soil pipes, and waste pipes which are wholly or partly inside of a dwelling or public building should be kept free from accumulation of foul gases or odors, and should be so freely vented that the water seals cannot be sucked out of the traps by siphonage, nor blown out by back pressure.

The necessity of ventilating all drain, soil, and waste pipes in a building is evident when we consider that no matter how well these pipes are cleansed by flushes of water passing through them, there will always be accumulations of solid matter upon their interior surfaces. These deposits decompose and evolve gases which are dangerous to a greater or less extent, according to their composition. In order to convey these gases from the pipe system, and allow them to discharge into the atmosphere, the vertical stacks are continued full size or larger up to and through the roof of the building where they terminate with open ends. A branch, known as the **fresh-air inlet,** taken from the lower part of the house-drainage system, is led to the atmosphere at another point for the purpose of admitting a supply of fresh air to take the place of the foul air that is ejected above the roof.

143. Fig. 56 shows a sectional elevation of a drainage system, and will be sufficient to illustrate the principles of drainage ventilation. The water closet A discharges into the soil-pipe stack B through the soil-pipe branch a. The bath C discharges into B through the waste pipe b. Drain air is prevented from entering the building by the bath trap c and

the water-closet trap, which forms part of the closet, and which is molded to it. A main disconnecting trap D prevents gases generated within the sewer E from flowing through the house-drainage system. The top of the soil-pipe stack B and the orifice of the fresh-air inlet pipe F are open to the atmosphere; consequently, when the air or gases in the drainage system are lighter than an equal volume of the outer atmosphere, they will flow up through the system and discharge into the atmosphere above the roof, as shown by

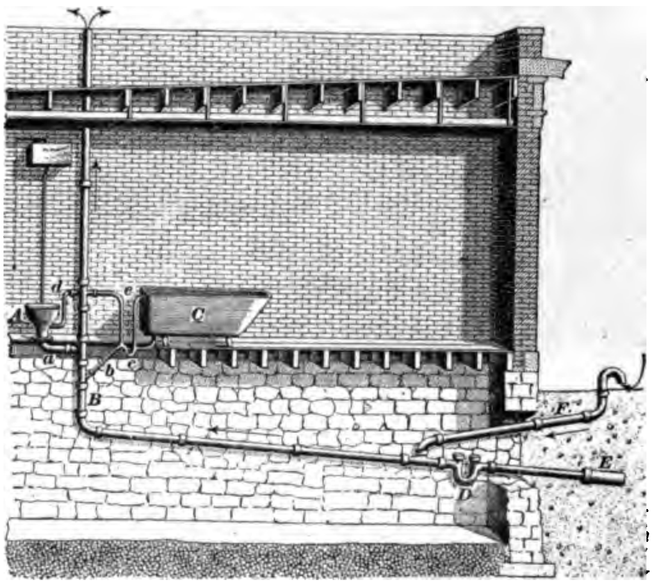


FIG. 56.

the arrows. They are displaced by a volume of fresh air flowing under atmospheric pressure into the system through the pipe F. This fresh air mixes with the gases, and, in turn, is soon ejected from the system. The velocity of a current of air flowing through a drainage system will vary considerably with changes in temperature, with the pressure upon the inlet or outlet orifices, etc. In many cases, the currents are reversed; that is, the drain air is forced out of

the fresh-air inlet pipe. Such would be the case if the water discharged from the fixtures should form a nearly solid plug while flowing through the pipe. The effect of the flush would be to force the drain air ahead. For this reason great care should be taken in selecting the point of fresh-air inlet. The branch pipes *a* and *b* are ventilated by back-vent pipes *d* and *c*, which join the main stack at their highest points. The principal use of these, however, is to prevent the siphoning of the traps when water flows through *a* or *b*.

144. The **location** of the **fresh-air inlet** is a matter of very great importance, and many things must be considered in selecting it. If the current of air which flows through the fresh-air inlet pipe always flowed inwards, the selection of the location of the inlet would not be such an important matter, but there are times when a **blow-back** actually occurs at the inlet orifice, which then becomes a temporary foul-air outlet. In order to prevent the drain air so blown back from being a dangerous nuisance to the inmates of the building, many of the health department laws compel the inlet orifices to be at least 15 feet from any window or door. This, of course, is to prevent blow-backs from entering the building.

Since the main house drains from nearly all city buildings are continued through the front wall and join the street sewer, and the fresh-air inlet pipe is, consequently, run from the main house drain at the front of the building, it stands to reason that if the inlet orifice must be 15 feet or more from the windows, the inlet of fresh air must be taken from a point near the street curb, or from a point above the building. It may be done either way, but the former method is usually employed. When taken from the curb, particular care must be exercised to avoid arranging the inlet orifice in such a manner that dirt or street sweepings may at any time enter and choke the pipe, thereby cutting off the flow of fresh air to the system.

145. A very common method of running the fresh-air inlet is shown in Fig. 57. The inlet pipe *a*, which joins the

house side of the main disconnecting trap in the cellar, is connected to a **curb box** *b*, as shown. The top of this box is sunk flush with the sidewalk and is fitted with a movable grating which can be lifted out or swung over the hinges to facilitate the cleaning of the box.

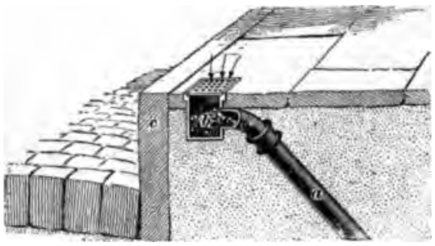


FIG. 57.

The chief objection to this method is that the box will gradually fill up with pavement sweepings, as shown, and the air will thus be choked off. It is also very much affected by snow storms. Even though the pavement is swept clean after a fall of snow, the perforations of the grating will remain clogged with snow and ice. In fact this form of fresh-air inlet, if not attended to, becomes practically useless.

To prevent any chokage by dirt, the pipe *a* is sometimes continued through the curbstone *c*, thus opening into the street gutter, and is provided with a grating over its mouth, which is set flush with the face of the stone. While this removes the objection to dirt accumulation, it is usually entirely closed while snow lies in the streets, the gutters being made the receptacles for the snow until it melts or is carted away.

Probably the best arrangement that can be employed for the average city building is the **perforated hollow hitching-post** arrangement, or a **perforated hollow stepping-block** arrangement placed over the mouth of the fresh-air inlet pipe.

146. In order to have the drainage system efficiently ventilated, it is necessary that the fresh-air inlet be the full size of the main drain, and that its caliber be unobstructed. When a grating is used over the inlet, the perforations should be at least equal in area to the sectional area of the pipe itself. This will reduce the resistance to the inflowing air to the minimum.

To make a fresh-air inlet pipe self-cleaning, it should have a pitch down to the main house drain greater than the angle of repose for dirt, say a little over 45 degrees. The dirt falling in will then slide down into the house drain and be carried to the sewer by discharges from the house fixtures.

Another method is to so arrange the pipes that periodical flushes of clean water will pass down the fresh-air inlet pipe, and so carry away all dirt accumulations. This may be accomplished by discharging area storm water, or roof water, into the inlet pipe above the dirt accumulations.

TESTING DRAINS, ETC.

147. Earthen drains should be carefully tested for leakage before the trenches are filled. The low end of the line of pipe should be plugged, and all branches should be stopped temporarily. The drain should then be filled with water, and allowed to stand full for a few hours. If the water settles down in the pipe, the leak should be found and stopped. A pressure of at least 1 pound to the square inch should be put upon every joint and pipe in the system.

148. All the drain, soil, waste, and vent pipes within a building should be thoroughly tested by water pressure, or the **hydrostatic test,** as it is called, before they are enclosed, and before the fixtures are attached. The pipes should be tightly plugged near the main trap or where they pass out of the building, and the end of every branch should be stopped water-tight. The system may then be filled with water, and the pipes should be allowed to stand full for several hours unless they are subject to frost, when they should be emptied before the water freezes. If the water sinks, then every pipe and joint should be inspected, and the leak found and remedied. A little more calking will usually suffice to stop a leaking joint in cast-iron pipes. However, if a cracked or split pipe or hub is found, the pipe should be removed, and a sound one should be put in its place. Patching or repairing should not be attempted; honest and durable work can be

done only by replacing the damaged parts with new and sound pipes.

149. The test by water pressure is applied only to the iron stacks, branches, and drain pipes; but it is just as important that the fixture connections be made gas-tight, so a **final test** is applied to them when the fixtures are all connected up and the traps sealed. The pressure of such a test must be less than that required to force the trap seals. To find whether the system is gas-tight, a **smoke test** should be applied.

A modern smoke machine, which is commonly used for testing plumbing, is shown in Fig. 58. It is connected by a rubber hose *a* to some pipes, which are joined as shown, merely for the purpose of illustrating the principles of the test. The smoke machine is essentially composed of a double-action bellows *b* and a firebox, which is shown, with fuel in it, at *c*. A water-jacket surrounds the firebox, and a cover or drum *d* is placed over the firebox so as to be sealed by water in the jacket, as shown. By the construction of the machine, it will be seen that if the lever handle *e* is moved sidewise, to and fro, air will be forced into the firebox, through the pipe which is provided with a three-way lever-handle shut-off cock *i*. The fuel in *c*, being ignited at the bottom, burns upwards, and the air supplies the oxygen necessary for a slow and incomplete combustion of the mass. Smoke, consequently, is given off from the surface of the fuel (which is generally old, greasy cotton waste gathered as scrap from the pipe vise) and is forced down through the hose *a* into the drainage system.

Now let the illustration represent a system of house drains, *f* being the main intercepting trap, *g* the main house drain, *h* the fresh-air inlet, *j* the soil-pipe stack, *k* the vent-pipe stack, *l* a fixture trap, and *m* its back-vent connection; let us proceed to test the system with smoke. We leave the tops of *k* and *j* open; then we blow dense smoke into the system. The smoke will fall down *h*, roll along *g*, and then rise up each of the vertical pipe lines and so push the air ahead of it out through the open ends on top. When the air

is all out, and the smoke consequently blows freely from the open ends in dense, heavy clouds, the ends are sealed air-

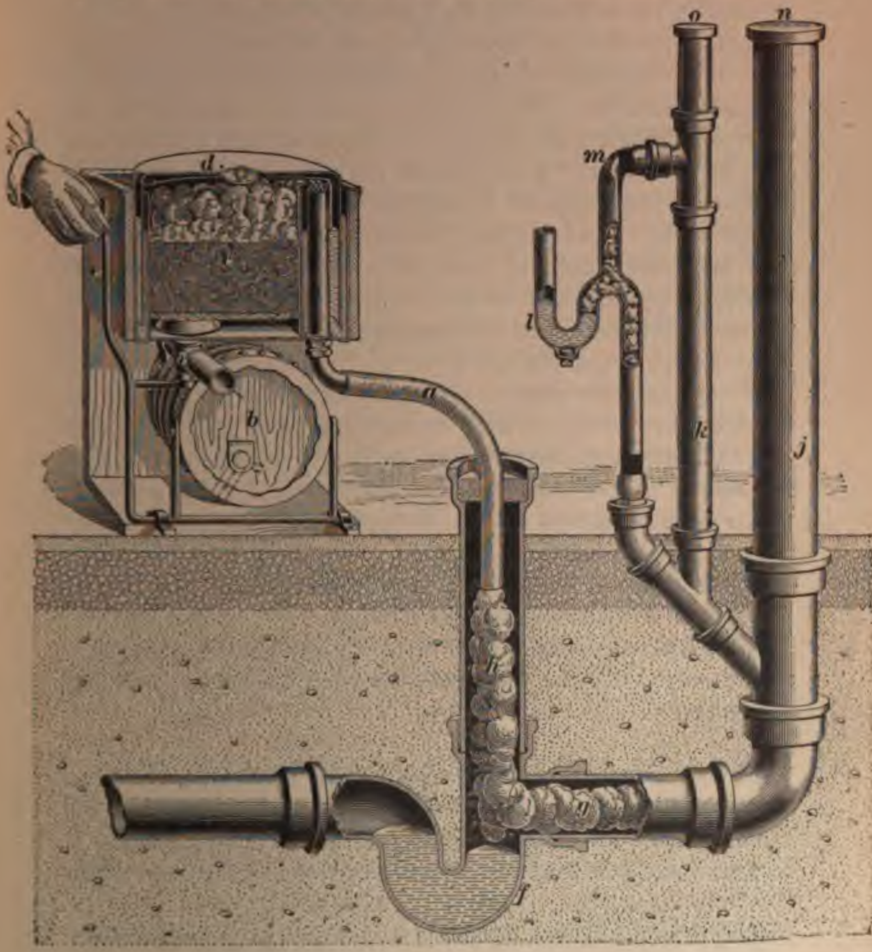


FIG. 58.

tight by laying a 6 or 7 pound sheet-lead cap over each, as shown at *o* and *n*. Of course, these caps must be bedded in putty or clay, so that they will be air-tight. The instant the ends are closed, the system is full of smoke at atmospheric

pressure, and it will be easily seen that, if the bellows continues to pump air into the firebox, the smoke will be compressed in the system and its pressure will increase.

As the pressure is increased in the system, however, so, also, is it increased in the firebox, and it will continue to increase until the upward pressure on the under side of the drum *d* overbalances its weight, when the drum will rise and float in the water. The pressure required to raise the drum is equal to that required to support a column of water about 1 inch high. In the figure, the drum is floating, a pressure of 1 inch water column is on the system, and the cock *i* is closed, to prevent the smoke from escaping down into the bellows. The effect of the pressure is also observed on the water in the traps *l* and *f*.

If any leaks are present in the system, they can easily be detected by smoke flowing from them, and the drum will descend with a velocity which will vary with the extent of the leaks. If everything is air-tight, however, the pressure will remain constant in the system, and the drum, consequently, will continue to float.

If the drum floats for a period of about 5 or 10 minutes, the system is usually passed as gas-tight.

If the trap seals are not forced with any pressure less than that required to raise the drum, the traps are passed as being safely sealed.

150. The **peppermint test** may be applied in the same way by putting some of the oil of peppermint into the apparatus instead of the smoking material. A more convenient way is to pour from 3 to 5 ounces of the peppermint into the top of the vent stack, and follow it up with a half gallon or so of boiling water. The hot water makes the peppermint more volatile and helps to diffuse the odor rapidly throughout the pipe system. All the outlets should be closed and the air pressure should be put on as before.

The smoke test is recognized as the most satisfactory test. It has the advantage, when properly applied, of exposing numerous defects which cannot be observed by other tests.

VENTILATION OF WATER-CLOSET APARTMENTS.

151. When a water closet is being used, an offensive smell is usually given off. This is partly taken away by the local vent (if any), and part of it will contaminate the air in the apartment. To remove the odor from the apartment, it is necessary to remove all the air in the apartment. The frequency with which the air in the apartment should be renewed will depend upon how often the closet is used. The air may be changed in various ways. The most common way is to simply open a window at top and bottom. This causes a circulation between the water-closet apartment and the outer atmosphere. This method of changing the air, however, is only suitable for mild weather.

A 4 or 6 inch bright tin or galvanized-iron pipe should be run from the ceiling just over the water closet or near it, to above the roof, where its orifice should be guarded by a properly designed ventilator cap or cowl. The orifice of the tube above the closet should be funnel mouthed to 12 or 14 inches in diameter.

The tube should, if possible, be run up alongside a hot chimney flue, so that the air within it may be rarified, and cause an upward draft. Advantage should be taken of the heat from burning gas jets in the apartment to facilitate the draft. This can be done by placing the light immediately under the funnel-mouthed inlet to the tube.

Dark water-closet apartments should in all cases be thoroughly ventilated, preferably, as explained above, by a tube with a gas jet burning within it or under it. The velocity with which the air travels up the tube will vary with the difference between the mean temperature of the air in the tube and the temperature of the outer atmosphere, also with the length of the tube and the number of bends, etc. in its length. In order to have the least resistance to the upward flow of the foul air, the pipe should be round or square in section, and should have as few elbows as possible.

When an exit is provided for foul air in the closet apartment, provision must also be made for an inlet of fresh air.

This is best done by having a space of 2 or 3 inches between the bottom of the door and the floor.

152. Latrines, or a number of single water closets in the same general apartment, are usually ventilated by one large ventilating tube run from the ceiling of the apartment. The closets are placed side by side with a 6 or 7 foot partition between. The door of each closet, being hinged about 6 inches above the floor, forms the fresh air-inlet for the small space enclosed. The foul air rising upwards discharges into the upper parts of the general apartment, and soon passes out through the ventilator.

DISPOSAL OF SEWAGE.

153. Sewage matter from buildings is disposed of in various ways, but chiefly by the following methods:

1. By a connection to the *main* or *street* sewer pipe or culvert.
2. By cesspools.
3. By direct or indirect discharge to the sea or rivers in close proximity to the building.

The first method is always adopted in well regulated cities having a system of sewage. For an ordinary residence, the pipe leading to the street sewer, called the *sewer connection*, is generally 6 inches in diameter, and is made of vitrified or salt-glazed fireclay spigot and socket pipes. It should be laid in a straight line between the disconnecting trap in the cellar and the street sewer. A handhole should be attached to the pipe in the cellar, so that in case of chokage, iron rods can be run through to the street sewer. The point at which this pipe joins the sewer should, if possible, be sufficiently high up the sides that the sewage cannot at any time back up in the sewer connections. The question of the disposal of sewage matter from buildings which are located in small country towns having no sewer system, is sometimes a difficult one. especially when the water supply is taken from wells.

154. Cesspools are commonly used to receive the filth from sinks and privies; but they are so liable to foul the soil for many yards in every direction, to pollute the air, and to poison all the wells in the vicinity, that they should never be employed if they can be avoided.

It seems almost incredible that rational people should deposit their slops and excreta in a pit which is dug in the same stratum of earth which contains the well from which they take their drinking water; yet, this is one of the commonest hygienic crimes perpetrated in rural communities. The frequent epidemics of typhoid fever, diphtheria, and scarlet fever, which have resulted from this practice, have led the State Boards of Health, in many states, to prescribe that no cesspool or privy vault shall be built or maintained within 150 feet of a well which furnishes water for drinking or cooking purposes. Even this distance is so unsafe that the local Boards of Health are empowered, in many states, to forbid them altogether if they think best.

If the ground is composed of gravel or loose stones, or coarse sand, the cesspool is generally built of loose stones without mortar, so that the water may filter away and leave the solid matter behind. The joints of the stones, however, soon become clogged with soap and grease, if the grease is not intercepted before reaching the cesspool, and the filtration is stopped. The cesspool then fills up and overflows.

If the ground is of a clayey nature, and no other method of disposal can be had, the cesspool will, of course, fill up, and it must be pumped out when full; the matter pumped out may be used as a fertilizer.

The cesspool should be dug as far as possible from the building, and should not upon any account be near a well, neither should the drain pipe leading to the cesspool be run near a well.

Cesspools should not be built air-tight, but should have a vent pipe discharging at a safe and proper distance from the house. A running trap also should be placed on the drain pipe near the cesspool, having a fresh-air inlet and vent cap

attached, so that a constant current of fresh air may pass through the drain.

Filtration is a most unsatisfactory procedure. The glutinous sludge soon chokes every description of filter.

155. If the sewage be discharged into a river or the sea, the outlet end should, if possible, be above high-water mark, so that high tides or rising of the river will not cause the water to flow up the sewer and perhaps choke it by backing up the solid matter. If the outlet must be below water mark, it should have a light brass flap valve attached to prevent fish, etc. from entering the pipe. It should also have a relief or vent pipe attached at a convenient point, to let out the air when a volume of water is passing down the drain—or when water backs up.

Crude sewage should not be discharged into rivers or streams whose velocities are low and volumes small, or where the velocity decreases between the point of sewage discharge and the mouth of the river, such, for example, as a deep or wide pool or dam in the river. As soon as quiet water is reached, the sewage matter will deposit there, putrefy, and pollute the river.

Neither should the crude sewage discharge into the sea at points where natural currents cannot be obtained to carry the solids seaward; because, if such a current cannot be obtained, the solid matter will be floated upon the beach and become a nuisance; or it will accumulate in mud banks and evolve offensive odors when agitated. The chief trouble to be found in discharging drains and sewers into the sea is that the sewage is *backed up* into the sewer twice in 24 hours. This is caused by the ebb and flow of the tide, and necessitates a good flush when the tide is low. The same trouble is experienced with tidal rivers.

156. By the irrigation method the sewage is conveyed to a tract of land composed of sand or light loam, if possible, where it is spread over or through the ground and constitutes the food of vegetation so far as derived from the soil.

There are many varieties of chemical treatments of

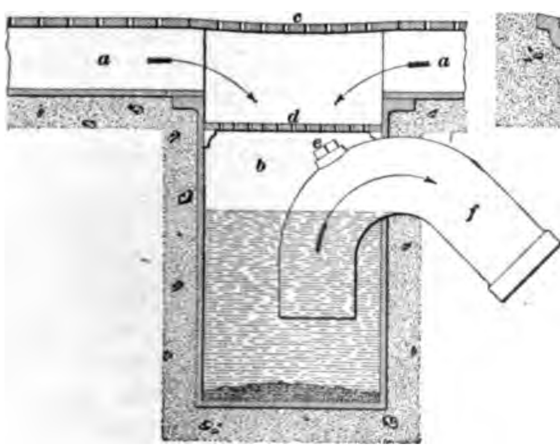
sewage, but it is not within the limits of this section to treat of any of them. The motive for chemical treatment is to convert the sewage into a fertilizer, or otherwise dispose of it.

157. The use of the **dry earth closet** in place of privy vaults for the disposal of human excreta, is rapidly extending among the more intelligent class of people. In this apparatus the excreta are covered with dry earth, preferably loam, or with the siftings of anthracite coal ashes. The ashes from bituminous coal are worthless for this purpose.

The quantity to be used on each occasion is about one quart, which is usually enough to absorb all of the liquids, and to neutralize all of the odors. The accumulations are received in pails, and are carried away at intervals to the garden or meadows as fertilizers. The sanitary advantages of this system are so great that it is likely to come into general use for outdoor closets for country homes.

STABLE DRAINAGE.

158. The waste water and urine from stables, etc. may be conducted away by gutters sunk in the floor. These gutters are usually made of cast iron and are covered by perforated plates, which can be readily lifted off for cleaning



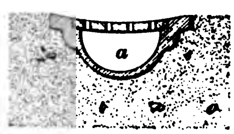


FIG. 59.

purposes. The entire floor surface should be graded, so as to drain into them. The gutter *a* may be laid with an inclination of about 1 inch in 10 feet, and should empty into a surface trap and catch basin *b*, as shown in Fig. 59. The solid matter will accumulate in the bottom as shown, and may be removed by lifting off the perforated covers *c* and *d*. Straw and such matter as might pass through the floor gratings is likely to be intercepted by the cover *d*. A tap screw should be provided at *e*, through which rods may be inserted in case the pipe *f* becomes choked.

The clean waste water from the hydrants or drinking troughs should, if possible, empty into the floor gutters at their highest ends, so as to flush and cleanse them.

WATER SUPPLY.

METHODS OF SUPPLYING WATER.

159. In the case of isolated buildings, such as country residences, the architect is frequently required, not only to specify fixtures and piping, but also means for procuring water. A slight knowledge of the machinery which is available for that purpose, is therefore necessary.

In city houses, machinery is used for pumping water into tanks on the top floors, when the pressure upon the street mains is insufficient to raise the water high enough to properly supply the upper floors.

For raising water to a moderate height from wells or cisterns, say about 10 feet, **chain pumps** are to be preferred, because they agitate, and thus to some extent aerate the water. They cannot be used for forcing, however, and when the lift is great, a piston or plunger pump must be used.

160. **Pneumatic pressure** may be employed to force water to a building by simply forcing the water into a large closed vessel furnished with an inlet and outlet pipe so attached that the air will be locked in the vessel and cannot be forced out with the flow of the water. An arrangement

similar to that shown in Fig. 60 will answer the purpose. An air-tight metal cylinder *A*, having an inlet pipe *a* connecting it to the delivery pipe *b* of the force pump

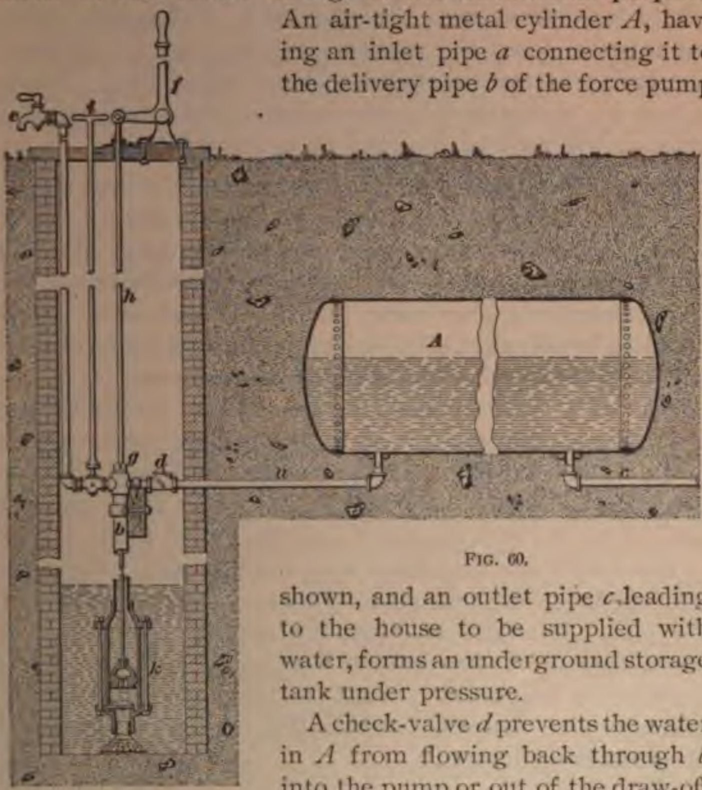


Fig. 60.

shown, and an outlet pipe *c* leading to the house to be supplied with water, forms an underground storage tank under pressure.

A check-valve *d* prevents the water in *A* from flowing back through *b* into the pump or out of the draw-off cock *e* above the surface of the ground. It will be seen that the plunger in the pump cylinder, which is under water in the well, is operated by the application of force to the handle of the bent lever *f*, the fulcrum of which is solidly bolted to a platform over the well. The pump shown is single acting, and it raises water with the up stroke of the plunger. A stuffingbox at *g*, through which the plunger rod *h* moves, makes a water-tight joint.

A stop and waste cock on the pipe which supplies *e*, can be operated by a T-handle key *i*. This is only for winter use to shut off water from *e* and drain its supply pipe below frost. This plan of underground storage has the advantage of always

keeping the water cool in summer and of storing it away where foul odors cannot contaminate it. It has also two disadvantages: First, the pressure will be irregular, gradually decreasing as the water flows from the cylinder. Second, unless air be forced into the cylinder, that contained in the cylinder will soon be absorbed by the water.

161. If a small stream of good water, having a fall of 5 feet or more, flows within a reasonable distance of the premises, a **hydraulic ram** may be used to great advantage to pump a steady supply of water into a suitable house tank. These rams are also made double, so that they may be operated by a stream of dirty or impure water, but take pure water from some other source and elevate it to the point desired.

The drive pipes which are attached to hydraulic rams should be of wrought iron or brass, because the hammering of the water columns will rapidly destroy ordinary lead pipes. They should not be less than 30 or 40 feet long, otherwise the weight of the driving columns will be too small. If two or more rams are used, each must have its own independent driving pipe; but they may all discharge into the same delivery pipe. If angles or bends are necessary in any of the pipes, they should be made by bending the pipes to as large a radius as practicable. Angles should not be made with ordinary pipe fittings, because they seriously impede the movements of the water.

162. When **windmills** are employed for raising water, it is especially necessary that the pumps, which are single acting, be provided with extra large air chambers, otherwise the mill is liable to hammer itself to pieces, or make an unbearable amount of noise.

163. **Hot-air engines** are very well adapted for pumping purposes. They require very little attention and use but little fuel. Care must be taken to avoid overheating them, and to keep them properly lubricated. If the engine is of the vertical type, the engine-house roof must be made high enough to permit the removal of the pistons by means of a block and tackle. There should be a hatch in the roof

large enough to allow the pump rods and tubes to be lifted out of the well.

When it is necessary for the pump to raise water to a height greater than 100 feet, such as is often the case in country buildings, a double-cylinder hot-air engine is most commonly used. With this class of engine, coal is generally used as the fuel, although furnaces can be had which will burn any kind of fuel.

These engines must be set upon a solid foundation, preferably a concrete floor, and the base should be bolted to the floor. They must also be set perfectly plumb, so that the pistons, which are very heavy, will bear equally all around. Hot-air engines are specially adapted for pumping where unskilled labor is employed to run them.

164. Another type of engine which has been recently perfected is the **oil engine.** This machine uses a small quantity of oil, varying in kind, from crude petroleum to gasoline, to a gas which is exploded in the cylinder of the engine. For the same power they are much smaller in size than hot-air engines. There is no danger connected with their use, except that which arises from the presence of the oil tank upon the premises. They require a certain amount of cooling water to be circulated through them. Usually the water which is pumped by them can be used for cooling, without objection. They can be used anywhere, and can be operated by almost anybody.

165. In towns where gas or electricity can be obtained, **gas engines** or **electric motors** may be employed to good advantage for pumping purposes.

For hotels, and other places which require a large amount of water, the **steam pump** is probably the best machine that can be employed.

WATER METERS.

166. **Water meters** are used to measure the quantity of water which passes through the service pipe to the building.

Meters should always be set level to secure proper operation of the working parts. They should be placed on the main service pipe, close to the point where it enters the premises, with a waste cock on the side next to the mains, so that the water may be drained from it when desired. An air chamber of generous size should be attached to the service pipe close to the meter, upon the inlet side, to absorb all the shocks that occur in the pipes.

167. The meter must be placed so that the dials can be readily observed. The method of reading the dials is about

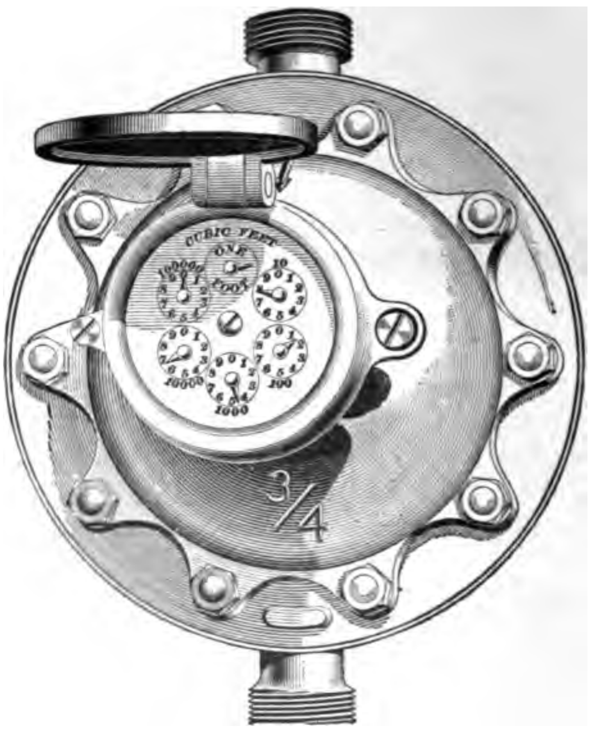


FIG. 61.

the same in all kinds of meters. Fig. 61 shows the ordinary arrangement. The figure to be taken is always that one

which the pointer has last passed, not the one which it is approaching. The figure which is indicated upon the dial, marked 10, must be put down first; that is, in the **units** place. To the left of it put down the figure indicated upon the dial marked 100; to the left of that put down the figure indicated upon the dial marked 1,000, and so on. Thus, the dials in Fig. 61 indicate 6,417 cubic feet. The small dial, marked **one foot,** indicates only fractions of a cubic foot. To find the quantity of water which has passed through the meter in any certain time, subtract the previous reading from the later one.

Great care must be taken to protect the meter, by means of a fine strainer, from the entrance of fish, sand, etc. The working parts are usually made of hard rubber, which is quickly destroyed by *hot water.* If there is any danger of hot water flowing back from the boiler to the meter, a meter should be used which has its working parts made of brass or bronze.

The accuracy of a water meter may be tested by weighing the water which passes through it. Several tests should be made, drawing the water slowly in some tests, and as rapidly as possible in others. An ordinary barrel will hold about 5 cubic feet, or between 350 and 400 pounds of water, and is of convenient size for this purpose.

Red or white lead should not be used in screwing up joints in meter connections, or the pipe which joins the meter to the source of water supply, because some of it is liable to reach the interior working parts and clog their movements.

All meters must be carefully protected from frost.

SIZE OF WATER PIPES.

168. The proper diameter of pipes which are to supply hot or cold water, depends upon several considerations:

1. The number and size of faucets that are likely to be discharging water at the same time.

2. The pressure or head of the water.
3. The length of the pipe.

If the pipe is crooked, making numerous bends or angles, due allowance must be made for the resistance arising therefrom.

A pipe of small bore, having great length, is likely to be noisy, if the pressure is great, being subject to singing noises and water hammer. This defect may be avoided by using a pipe of larger diameter, thus reducing the velocity of the moving water.

169. Horizontal pipes may be reduced in diameter as various branches are taken off. This is done only to economize in the cost of pipe, etc. An example of such reduction is shown in Fig. 62. In this the nearly horizontal

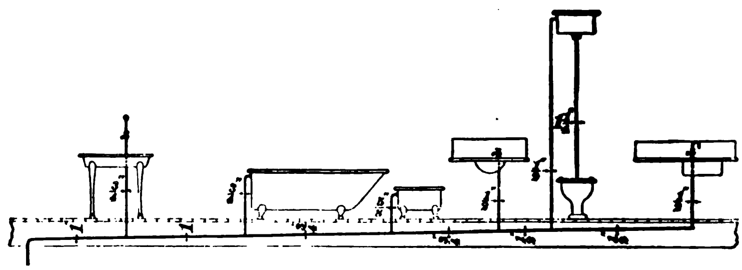


FIG. 62.

distributing pipe is reduced from 1 inch to ½ inch as the branches are taken from it.

Suppose that the distributing main should enter at the opposite end so that the pantry sink branch would be taken off first, then it would only be reduced one size, that is, from 1 inch to ¾ inch, because its extreme end must equal that of the sink branch. It is well to have the distributing mains a little too large rather than too small; the annoyance of one faucet robbing another will then be avoided.

170. Vertical pipes, which descend from a tank, may be reduced in a similar manner, as shown in Fig. 63. The

tendency of the water flowing from the tank *A* is, of course, to fall to the bottom of the vertical line of pipe, and flow out of the lower branch. Although the vertical line is decreased in size as it descends, it still follows that there is a greater pressure upon the lower branches than upon the higher, and to compensate for this difference in pressure, the sizes of the branches upon the different floors should be decreased as they descend. Thus, in the figure the top branch is 1 inch and the lowest ½ inch. By this system of distribution a nearly uniform supply of water can be given to each floor in a high building.

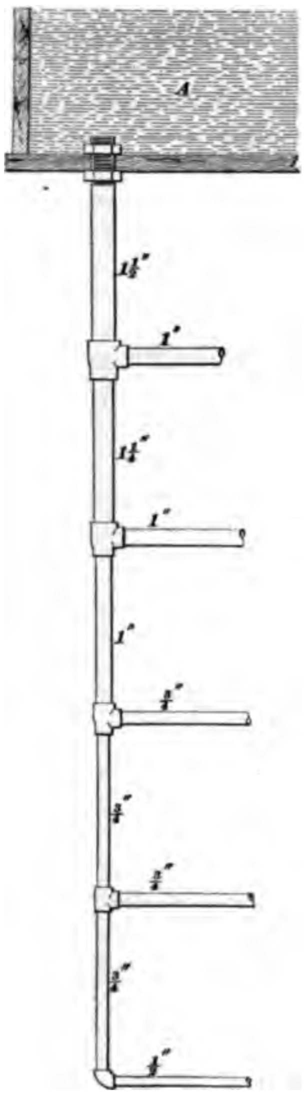


FIG. 68.

Pipes which rise from a service pipe in the basement and ascend to the upper stories, usually should not be reduced in diameter, until the last branch is reached. This is because the pressure grows less as the height increases, and to secure a satisfactory flow on the upper floors, the pipes must be large in diameter. Even if the head is so great that there is plenty of force on the upper floors, if the pipes be reduced in diameter, they will be liable to annoyance from the action of the faucets in the lower stories. If a faucet in the basement be opened, for example, the flow from a faucet on the top floor, which happens to be open at the same time, will be checked or even stopped.

171. The size of the corporation cock which may be attached to a street main is usually determined by the water department. The diameter of the service pipe should not be governed by the size of the corporation cock, however, but should be determined solely by the requirements of the building. If the quantity of water required is very large, the water authorities will, upon due presentation of the facts, usually allow a larger connection to be made to the water mains.

172. The following sizes of branches are commonly used in buildings where the pipes are not of great length. If the pressure is less than 20 pounds per square inch, the system may be rated as *low pressure*, and if above 20 pounds as *high pressure:*

TABLE 7.

Supply Branches.	Low Pressure.	High Pressure.
To Bath cocks	$\frac{3}{4}$ to 1 inch	$\frac{1}{2}$ to $\frac{3}{4}$ inch
To Basin cocks	$\frac{1}{2}$ inch	$\frac{3}{8}$ to $\frac{1}{2}$ inch
To W. C. flush tank	$\frac{1}{2}$ inch	$\frac{1}{2}$ inch
To W. C. flush valve	1 to $1\frac{1}{4}$ inches	$\frac{3}{4}$ to 1 inch
To Sitz or foot baths	$\frac{1}{2}$ to $\frac{3}{4}$ inch	$\frac{1}{2}$ inch
To Kitchen sinks	$\frac{5}{8}$ to $\frac{3}{4}$ inch	$\frac{1}{2}$ to $\frac{5}{8}$ inch
To Pantry sinks	$\frac{1}{2}$ inch	$\frac{3}{8}$ to $\frac{1}{2}$ inch
To Slop sinks	$\frac{5}{8}$ to $\frac{3}{4}$ inch	$\frac{1}{2}$ to $\frac{5}{8}$ inch
To Urinals	$\frac{5}{8}$ to $\frac{3}{4}$ inch	$\frac{1}{2}$ to $\frac{5}{8}$ inch

PURIFICATION OF WATER.

173. The impurities which occur in ordinary waters are of two kinds; namely, mechanical, or those held in suspension by the water; and physical, or those held in solution. The mechanical impurities are mud, leaves, vegetation, fish, frog spawn, insects, insect eggs, etc. The

physical impurities are solutions of minerals, putrescent animal matter, albuminous slimes, etc. The leachings from privy vaults and drains are the most harmful poisons that usually get into the water supply.

The mechanical impurities are far less dangerous. They are easily seen and may be removed by passing the water through a bed of sand. This will strain out everything which is visible. The danger, however, lies mainly in the pollutions which are invisible. Mineral poisons can be neutralized by the use of chemicals, and sometimes by heating and settling. The organic poisons from sewage, etc. can be removed only by careful filtration through sand to remove all mechanical impurities, etc., and then through bone charcoal. This material exerts a chemical action upon the organic matter in the water, and renders it inert or harmless. The charcoal, however, gradually becomes saturated and clogged with the refuse, and loses its chemical powers. Therefore, it must be renewed at intervals.

The animal charcoal is made from bones, and is hard and dense. When its pores become clogged with refuse, it can be restored to usefulness only by reburning. There is no practicable way by which this can be done upon a small scale. Unless the air is carefully excluded during the whole process, the material will be consumed, like other charcoal, and will be destroyed.

Charcoal which is made from wood has little or no value for the purpose of filtration.

174. Water which has grown stale by standing may be greatly improved, and be made suitable for drinking purposes, by the process called **aeration**, provided it has not been otherwise polluted.

Aeration may be accomplished in several ways. The water may be squirted into the air in fine streams; air may be forced through the water in fine bubbles; or air and water may be shaken up or otherwise agitated together. The object to be attained in every case is to expose the water to the action of the air to the greatest practicable extent.

In the process of aeration the water absorbs a considerable quantity of air, and is thereby greatly improved in appearance and taste. The air has a mild oxidizing effect, which is sufficient to destroy a small amount of vegetable matter and render it harmless. But this purifying influence is very limited in extent, and is of no use whatever for removing or destroying the germs of putrefaction, fermentation, and disease which are imparted to the water by sewage or house drainage. These germs can be killed only by boiling, and some certain disease germs cannot be certainly killed even in that way.

The process of aeration is thus adapted only to the purpose of *freshening* water and rendering it more palatable, and is not serviceable for actual purification.

In all apparatus designed to aerate water, care must be taken to thoroughly exclude all dust from the air, because dust is very apt to carry with it many kinds of germs which give rise to putrefaction and disease. Dust must be kept out of food and drinking water.

175. Rain water which is taken from the roofs of buildings is always more or less contaminated with leaves, dust, excreta of birds, dead insects, etc. If it is desired to use any of this water for drinking or cooking purposes, the pipes which lead it to the cistern, or the cistern itself, should be supplied with a device called a *rain-water cut-off.* This is an apparatus which turns all of the water from the rain leaders to waste until the roofs are washed clean, and then turns the water into the cistern. The water which falls during the first few minutes of a rain storm is loaded with dust and insects, but after twenty minutes or so it is usually very pure.

FILTERS.

176. In all varieties of filters the velocity of the water passing through them should be low enough to permit the finest sediments to deposit themselves upon the surface of the beds of filtering material. Otherwise, in treating muddy water, it will retain a muddy color.

The velocity of the water passing through a filter bed of bone charcoal, should also be low, so that the water may be in contact with the charcoal as long as possible, the chemical changes in the impurities thereby being more complete. The beds of filtering material become gradually clogged by the accumulation of refuse upon the surface of the bed and upon the grains of sand or charcoal; the flow of water is checked and the usefulness of the apparatus is greatly impaired. This can be remedied by *reversing* the direction of the flow of water, at suitable intervals. Thus, the accumulations can be washed away and be run to waste, and the filter can be operated almost continuously.

A filter which cannot be thus reversed should not be employed if possible to avoid it, because the care and trouble which will be required to keep it in good working order, will be so great as to lead almost certainly to neglect. A filter which is neglected is likely to become foul, and thus give rise to the very danger that it was intended to prevent.

There are so-called filters which are made to screw upon the nozzle of an ordinary faucet. They consist of a cup having a filling of bone charcoal or other filtering material, and they operate only as strainers, to hold back the insoluble impurities which are carried by the water. They do not purify the water except in a mechanical way. The bone charcoal has no purifying effect upon it, because it passes through far too rapidly for any chemical effect to take place.

177. Filters should be kept full of water. They should not be allowed to become dry, nor to be exposed alternately to water and to air. Alternate wetting and drying of putrescible matter greatly hastens putrefaction and increases the growth of disease germs, etc. A filter which is thus operated is liable to become a source of poison instead of a protection against it.

In cities and towns having a water supply which is liable to become muddy at times, dwellings should be supplied with a filter, located in the basement. All of the water which enters the house should pass through the filter. This will

prevent the kitchen boiler from filling up with mud, and will insure clean water throughout the building.

178. The mode of constructing an ordinary filter, suitable for rain water, etc., is shown in Fig. 64.

The body of the filter is built of brick, laid in mortar composed of Portland cement mixed with an equal volume of clean, sharp sand, and it is divided into two chambers by

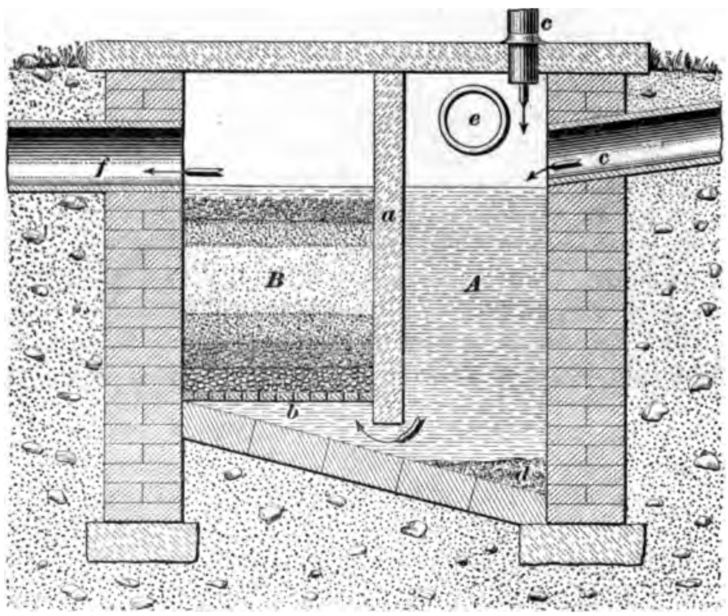


FIG. 64.

means of a partition slab *a* of slate or flagstone. The bottom of the chamber *A* is provided with a low place or pocket *d* in which may gather sediment, and from which it may be removed by the garden pump or other convenient means. The chamber *B* is fitted with a perforated bottom *b* upon which is placed a course of gravel, then clean sand, nearly up to the level of the discharge pipe *f*. It is then topped with gravel. The rain water enters chamber *A* through the pipes *c*, *c*, and deposits any solids that may accompany it into the pocket, as shown at *d*. It then flows upwards through

the sand in chamber *B*, which clarifies it. Chamber *A* is also provided with an overflow pipe *e*, so that if the filter becomes choked with dirt, the water will not acquire sufficient head to force the dirt through the filter; the pipe also acts as an overflow for the cistern into which *f* delivers.

SUPPORTS FOR PIPES.

179. Lead pipes 2 inches in diameter and less, which run against walls, etc., are usually supported by means of flanges, or **pipe tacks,** which are soldered on to the pipe at convenient intervals, and are fastened to the walls with common wood screws, as illustrated in Fig. 65, which shows a $\frac{3}{4}$-inch lead pipe *a* secured to a wall or pipe board *b* by *molded pipe tacks c, c* and 1-inch wood screws *d, d.*

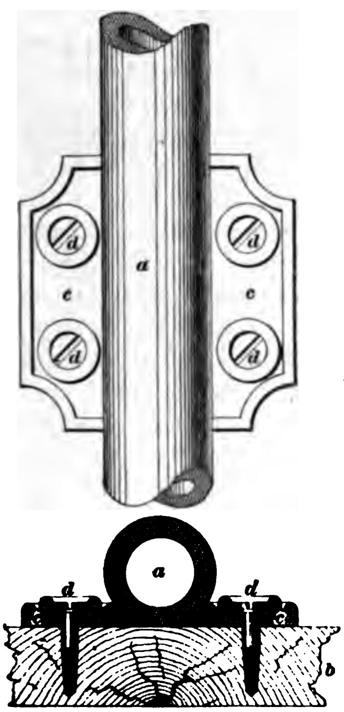


FIG. 65.

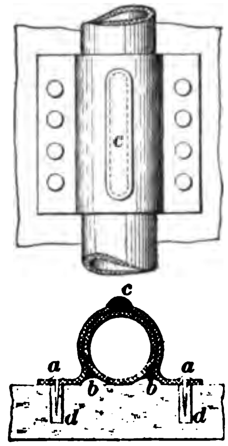


FIG. 66.

The tacks are made of old lead, slightly hardened with a few old wipe joints mixed in. They are cast in brass molds.

180. Pipes over 2 inches in diameter are best supported by means of broad **bands,** such as shown in Fig. 66, which

are attached at intervals of about 3 or 4 feet. The width of the bands, along the line of the pipes, measured for pipes of 2, 3, or 4 inches diameter, should be about 6, 8, or 10 inches, respectively. An oblong hole *c* is cut in the front of the band, and is filled with hot solder and wiped to the face of the pipe. The side flanges of the band are wiped to the face of the pipe, as shown at *b*. The band is shown secured to a stone wall by flat-head spikes *a*, driven into wooden plugs *d*, which have been previously driven into holes cut into the stonework.

181. If the temperature of a lead pipe, which is supported by rigid fastenings, is maintained nearly uniform, as is the case of the cold-water supply pipes, the pipe can only be changed in form by its own weight, the jarring of the building, etc. If, however, the temperature of the pipe is variable, as is the case of the pipes which supply hot water to the plumbing fixtures, the pipes will expand as the temperature increases, which causes them to bulge between their supports. Lead is so very low in elasticity that when the pipe becomes cool, the sags are not entirely taken up by contraction; and upon every application of heat, the sags will increase in size, particularly on horizontal pipes, until the lead becomes so thin near the points of support as to cause a leak. The leak generally occurs in a crack which is formed around that part of the pipe near the tacks.

Suppose that a lead waste pipe 2 inches in diameter, secured in a vertical position against a wall by hard-metal tacks or lead bands, has a kink in it, and that hot water passes through the pipe periodically. It will be found that since the kink is the weakest part of the pipe, it will take up most of the expansion between the tacks on each side of it. This action subjects the kink to a cross strain, repetitions of which will soon overcome the cohesive strength of the lead and cause the metal at that point to crack. Kinks should be carefully avoided in all lead-pipe work. A kink in a lead waste pipe is a positive sign of slovenly, careless, or ignorant workmanship, and should not be tolerated.

182. When a hot-water pipe runs horizontally, it is better to support it upon a continuous ledge or shelf. It should have room enough laterally to bend and creep, and should be kept from working off the shelf by a suitable rim or flange along the edge of the shelf.

Lead pipes should not be supported by iron wall hooks or similar supports, unless they are protected by an extra thickness of sheet lead between them and the iron, because the edges of the iron will gradually cut into the lead and thus weaken the pipe.

183. The approximate spacing for tacks on lead pipes is given in the following table:

TABLE 8.

Size of Pipe. Inches.	Vertical Pipe. Distance Apart. Inches.		Horizontal Pipe. Distance Apart. Inches.	
	Hot.	Cold.	Hot.	Cold.
$\frac{3}{8}$	18	24	12	16
$\frac{1}{2}$	19	25	14	17
$\frac{5}{8}$	20	26	15	18
$\frac{3}{4}$	21	27	16	19
1	22	28	17	20
$1\frac{1}{4}$	23	29	18	21
$1\frac{1}{2}$	24	30	18	22

184. *Vertical pipes of lead* are usually supported, where they pass through floors, by means of a flange or collar, which is wiped to the pipe, or a flange joint is made at that point. The diameter of the flange should be about 2 inches larger than that of the pipe, to give room for wiping.

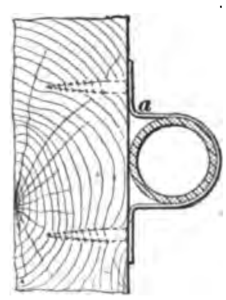


FIG. 67.

185. *Wrought-iron pipes* may be fastened in place by common drive hooks, but where a good appearance is desired, they should be fastened with bands, which are secured to the walls

by screws, as shown in Fig. 67. The band or strap *a* should be made of wrought iron, tinned.

Brass pipe may be similarly supported, making the bands of brass. It is usually supported, however, by specially made clamps or pipe hangers, which are first attached to the walls, the pipes being afterwards laid into them and locked there by closing the outer half of the clamp, which is hinged to the main body. Such supports usually hold the pipe at a little distance from the walls; this prevents vermin from lodging around them, and also allows them to be polished conveniently.

186. *Cast-iron soil and vent pipes* should be strongly secured in place. Vertical stacks should rest upon a solid support at the bottom. If an elbow occurs at the base of the stack, it should be provided with a flat foot, or **heel rest,** as shown at *a*, Fig. 68.

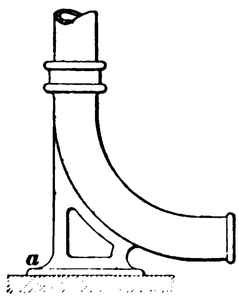


FIG. 68.

The weight of the pipe should be borne entirely by the base support. The pipe should be held in place by means of hooks or bands, which are placed at intervals of 5 feet or less, according to the nature of the work.

The pipe may also be secured against the face of a stone wall by means of a wrought-iron band *a*, as shown in Fig. 69. Two holes *b*, *b* are cut into the stone, and the ends of the band are calked in the holes with lead. This style of fastening is neat and reliable.

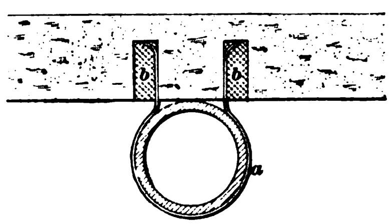


FIG. 69.

All hooks or bands should clasp the pipe close under the hub, or around it, and should not be placed midway between the joints, if it is possible to avoid it.

If the pipes stand in a chase or groove in the wall, they may be fastened by means of clamps, or **pipe rests**, *a*, which are secured in notches *b*, *b* cut in the wall, as shown in Fig. 70.

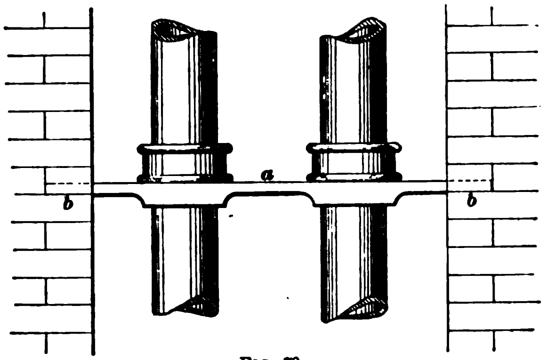


FIG. 70.

187. Care must be taken that the fastenings are so arranged that the pipe will be free to contract and expand with the changes of temperature without loosening itself, or tearing the fastenings loose from the walls. Buildings are always liable to settle, and this must be kept in mind when locating the pipe fastenings.

Iron drain pipes which run inside of basements or cellars, should be thoroughly supported by wrought-iron straps fastened to the beams overhead, or else they should be supported at short intervals upon brick piers, or by wall hooks driven into the brick or stone walls.

A substantial pier should always be placed under each stack. In all cases a firm support should be placed under the junction of the stack with the inclined drain pipe. All stacks should be supported independently of the main drain, so as to relieve the inclined pipe of the weight of the stack.

SYSTEMS OF PLUMBING AND DRAINAGE.

188. The student having now become familiar with the principal details of plumbing and drainage systems, we will proceed to illustrate, by the following figures, or plans, how the several parts, when properly fitted up, form what are

known as **plumbing** and **drainage systems**, or, more properly speaking, systems of house drainage and systems of water supply and distribution.

The systems shown, although they do not cover the entire field of house plumbing and drainage, are so arranged as to show clearly to the student what is considered good modern practice in the United States. We advise the student to carefully study these drawings until he fully understands the use of every pipe and fixture shown.

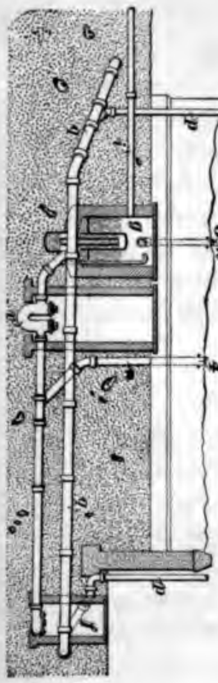
PLAN NO. 1: OUTSIDE HOUSE DRAINAGE.

189. Fig. 71 shows in plan and sectional elevation a system of drainage suitable for an isolated building. Water is assumed to be scarce, and the rain water falling upon the roof of the building is collected and stored in a brick and cement cistern. The sewer pipe is supposed to be very long, and to have a very slight fall towards its outlet. To keep the drains clean with a minimum expenditure of water, the waste water from some of the baths and wash basins is collected in an automatic flushing tank and discharged, periodically, for flushing purposes. Of course, when this is done the bath and basin stacks must be carried separately up to and through the roof, and have no connection with the closet, soil, or vent pipes. It will be noticed that all the pipes are run immediately through the main walls and underground. This avoids running horizontal pipes in the basement or under the floors of the building, thereby reducing the danger from leaks to a minimum.

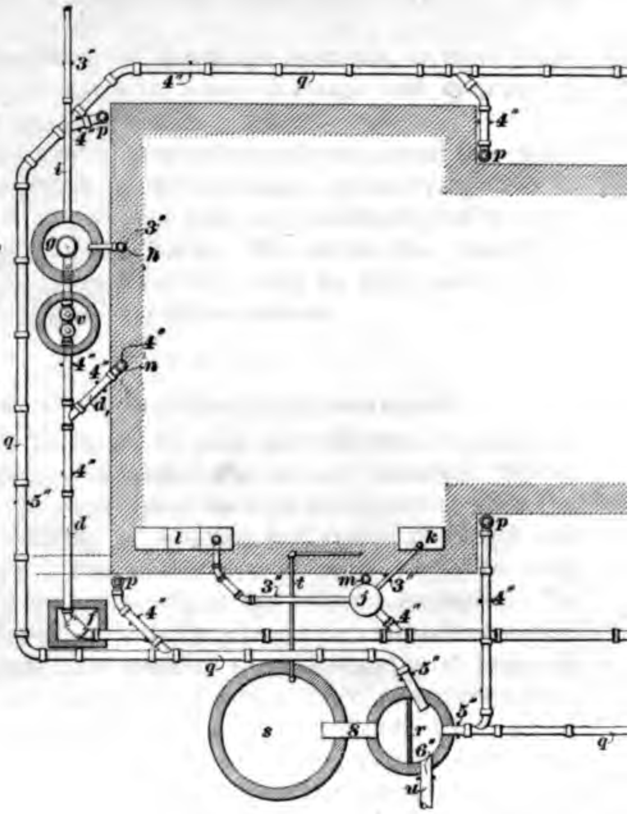
The building is shown in block plan, its main walls being shown at *A*.

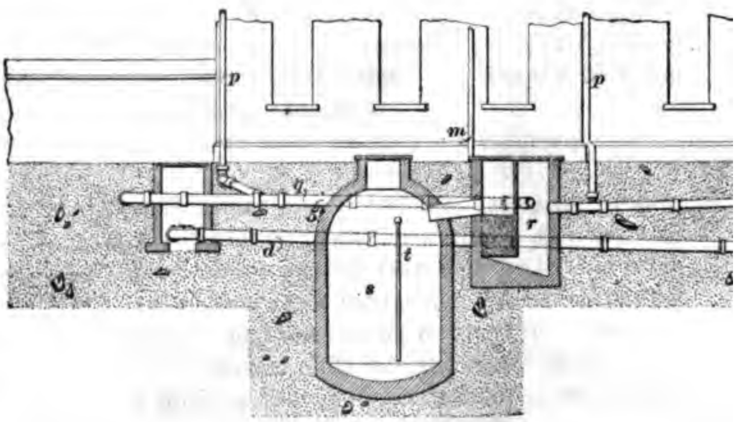
The 6-inch earthenware pipe *a* is the house sewer proper. It conveys all of the sewage from the building to a suitable outlet. The main disconnecting trap *b* is built in a brick manhole. An inspection piece into which the drains *d* discharge, and the fresh-air inlet *e* joins, delivers into the trap. A closed inspection piece is built into the manhole *f*.

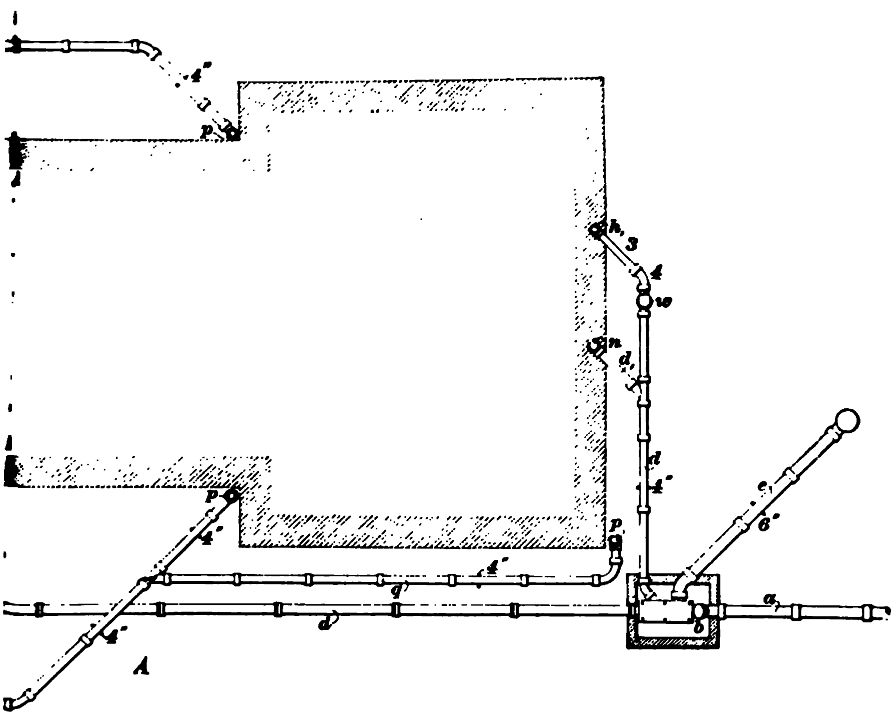
An automatic flushing tank *g* is connected to the highest



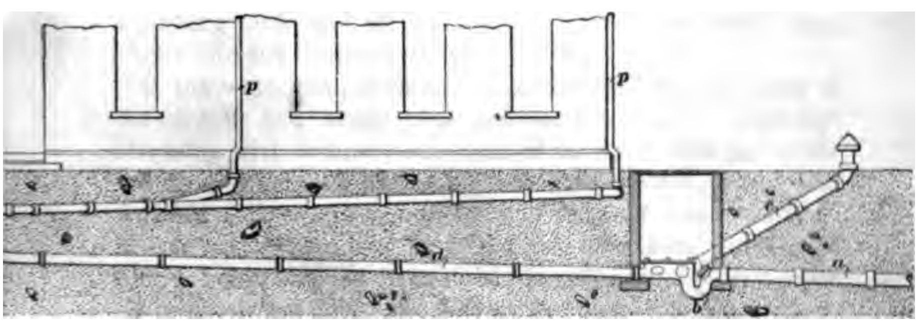
C







A



B

end. This receives discharge from the bath and basin waste *h*. The pipe *i*, led to a convenient point, is a fresh-air inlet to *g*, while *h* acts as an outlet.

A grease trap *j* intercepts grease, etc. from the sink *k* and laundry tubs *l*, and is ventilated to the roof by a 3-inch pipe *m*, a few holes being made in the cover for an air inlet.

The branch drains d_1, d_1 connect the soil-pipe stacks *n*, *n* to the main drains. The discharge from baths and basins connected to the waste stack h_1, enters the drains direct.

The roof water falls in the leader or conductor pipes *p* into the selected stoneware rain-water pipes *q*. These pipes convey it to the filter *r* through which it must flow before entering the cistern *s*, from which it is drawn to the building by a pump attached to the suction pipe *t*. An overflow for the filter, that is, for the cistern, is shown at *u*.

The trap *v* disconnects the flushing tank from the drains, so that when the tank is empty it will not be flooded with drain air.

A small air pipe which turns over in the tank *g*, prevents air lock between *g* and *v*. A handhole *w* is placed upon the drain for easy access.

190. Should the water supply to this building be abundant and the roof water be permitted to flow to waste, the best method then would be to run all the rain-water drains into a flushing tank, and all the discharge from the several pipe stacks into the drainage system direct.

If the water supply should be abundant and the pitch of the drains and sewer pipe sufficient to insure thorough cleansing with ordinary methods of flushing, that is, by the simple discharge from the fixtures, the cistern, filter, and flushing tank would be omitted and the roof water would all deliver into the drains, the rain-water drains and leaders, of course, being trapped from the drainage system, so that drain air or sewer gas could not flow up the rain-water leaders, or conductors, and be discharged into or near windows. The grease trap, however, should remain, but the laundry tubs need not deliver into it.

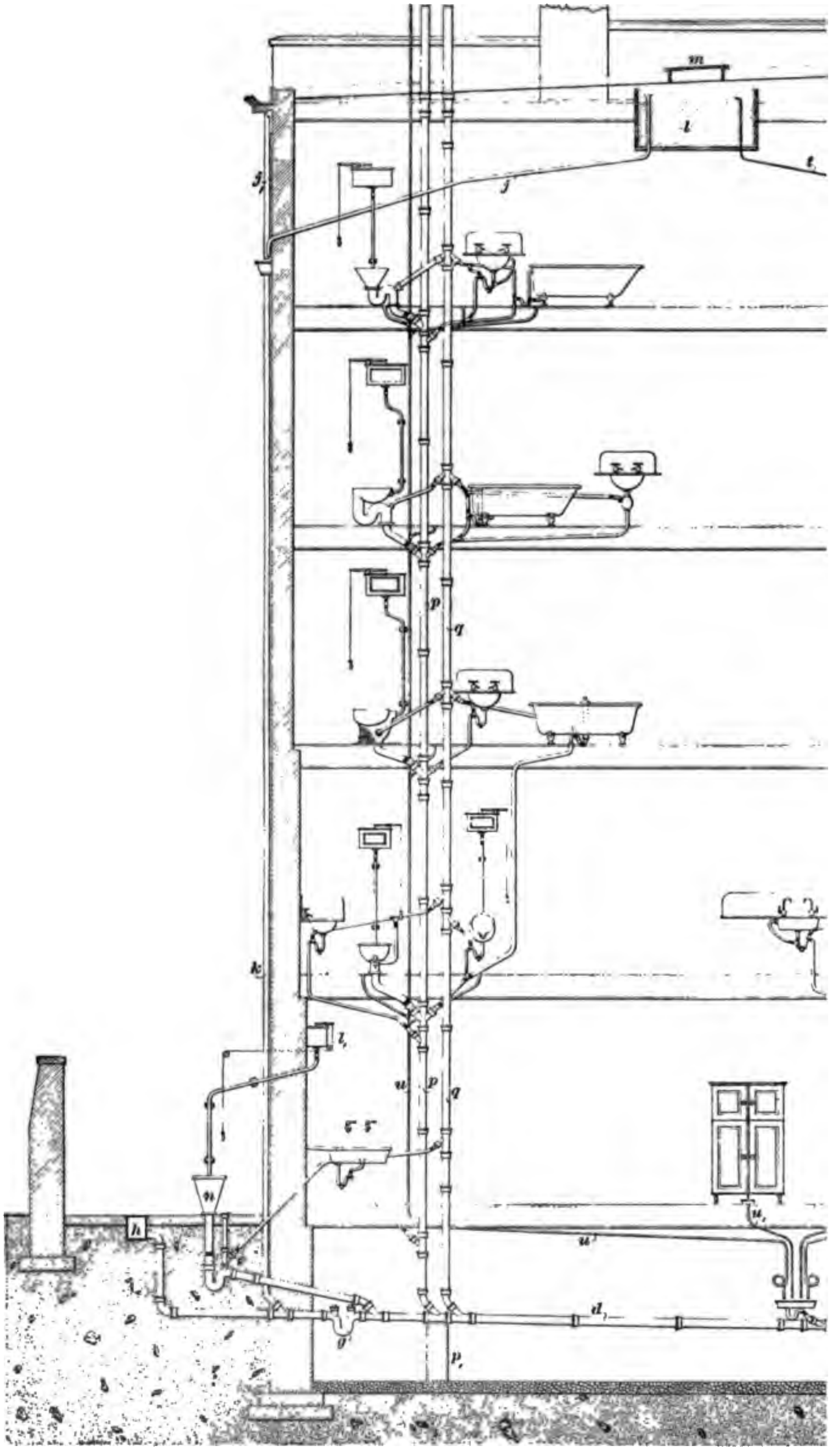
PLAN NO. 2: INSIDE HOUSE DRAINAGE.

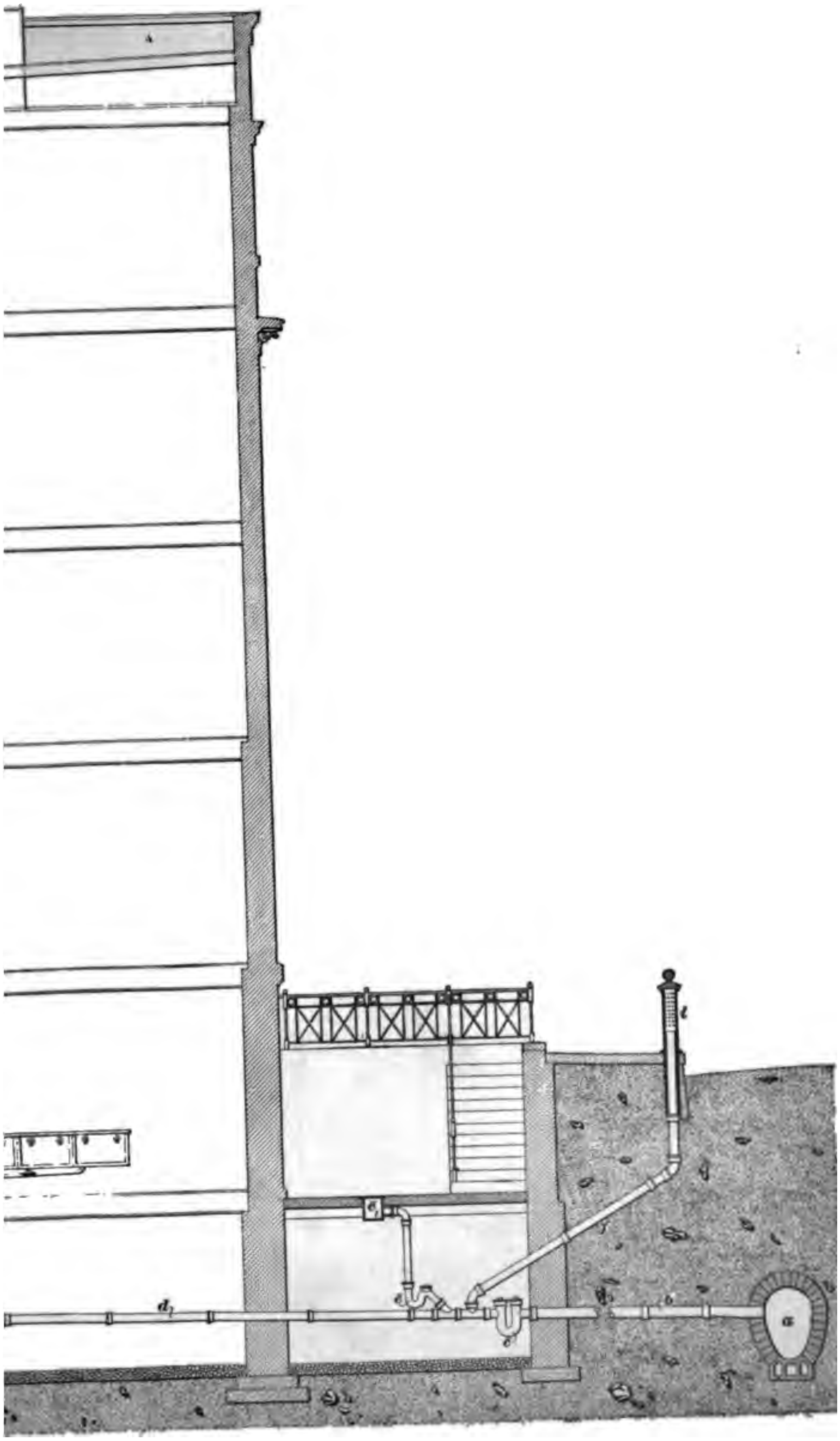
191. Fig. 72 shows, in sectional elevation, a system of drains, soil, waste, and vent pipes for a city building. All of the sewage from the building is discharged into the street sewer *a* by a 6-inch fireclay pipe *b*, which is broken to show that the sewer is farther away from the building than it appears in the cut. A 5 or 6 inch iron disconnecting trap *c* is placed just inside the cellar wall. The 5-inch house drain *d* is run along the face of the cellar wall. A 4-inch pipe, furnished with a deep seal trap *e* in the cellar, carries away surface water from the catch basin c_1 in the front area. A 5-inch fresh-air inlet pipe *f* takes a supply of fresh air from the street curb by means of a perforated post inlet *i*, as shown, instead of a plain grating flush with the pavement. A 4-inch deep seal trap *g* disconnects the back area surface water box *h* and the roof leader *k* from the house drain. The rain-water pipe j_1 and the tank overflow pipe *j* both deliver into a rain-water head upon the rain-water pipe *k*.

The fixtures in the basement floor are a kitchen sink, a set of three laundry tubs, and a refrigerator. The fixtures upon the first floor are a butler's pantry sink, a corner wash basin, a water closet, and a urinal, the closet and urinal both being flushed from small tanks overhead. In ordinary private house work the three latter fixtures would be omitted. They are connected up in the drawing only for illustration, as they may, in exceptional cases, be employed. The fixtures on the second floor are two wash basins, a Roman bath, and a siphon-jet closet. The fixtures on the third floor are two wash basins, a French bath, and a front outlet washout closet.

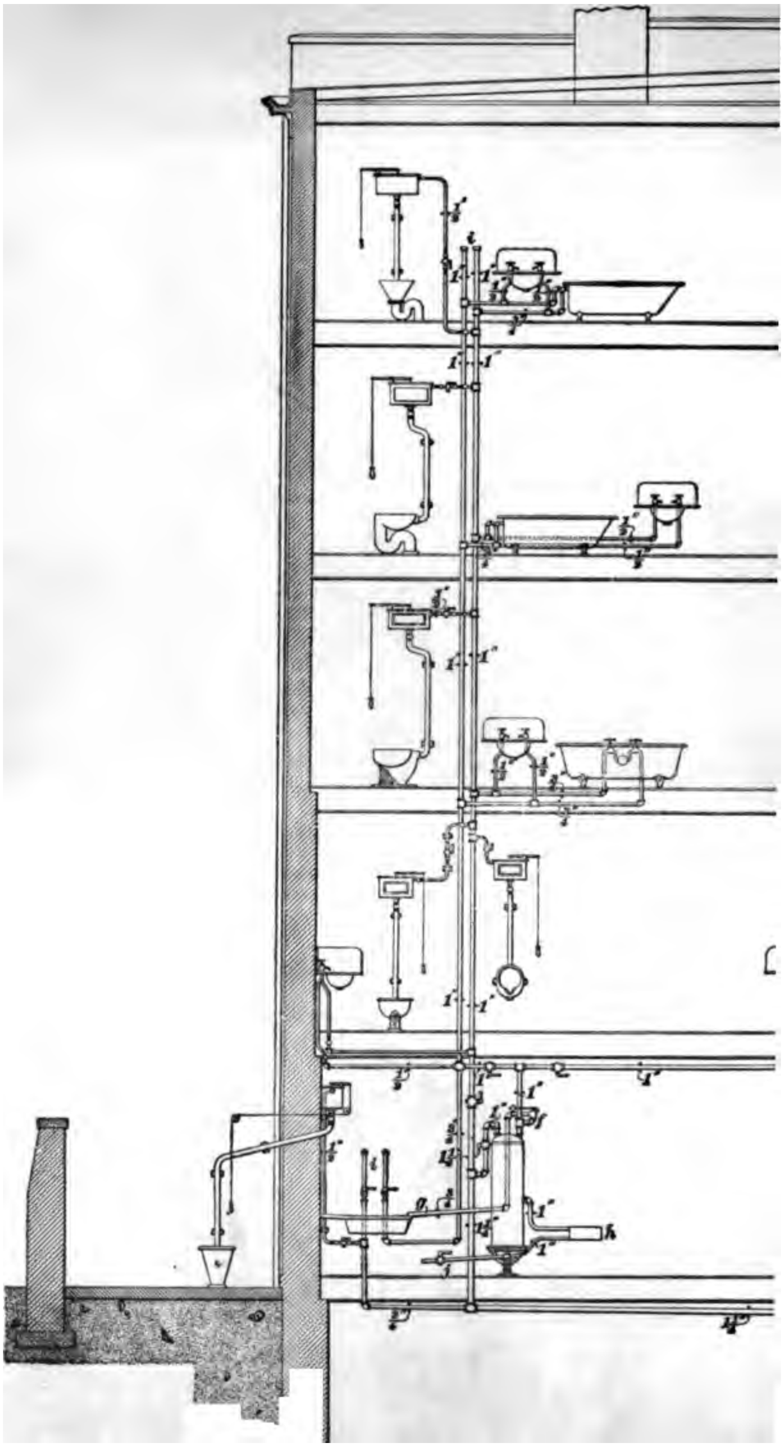
On the top floor, for the servants' use, is located a common iron bath, a plain wash basin, and a short hopper closet. A rectangular, copper-lined, wooden house tank *l* is also placed on the fourth floor, high enough to supply the small tank for the hopper closet, and a hatch *m* about 20 inches by 30 inches is made on the roof for access to the tank.

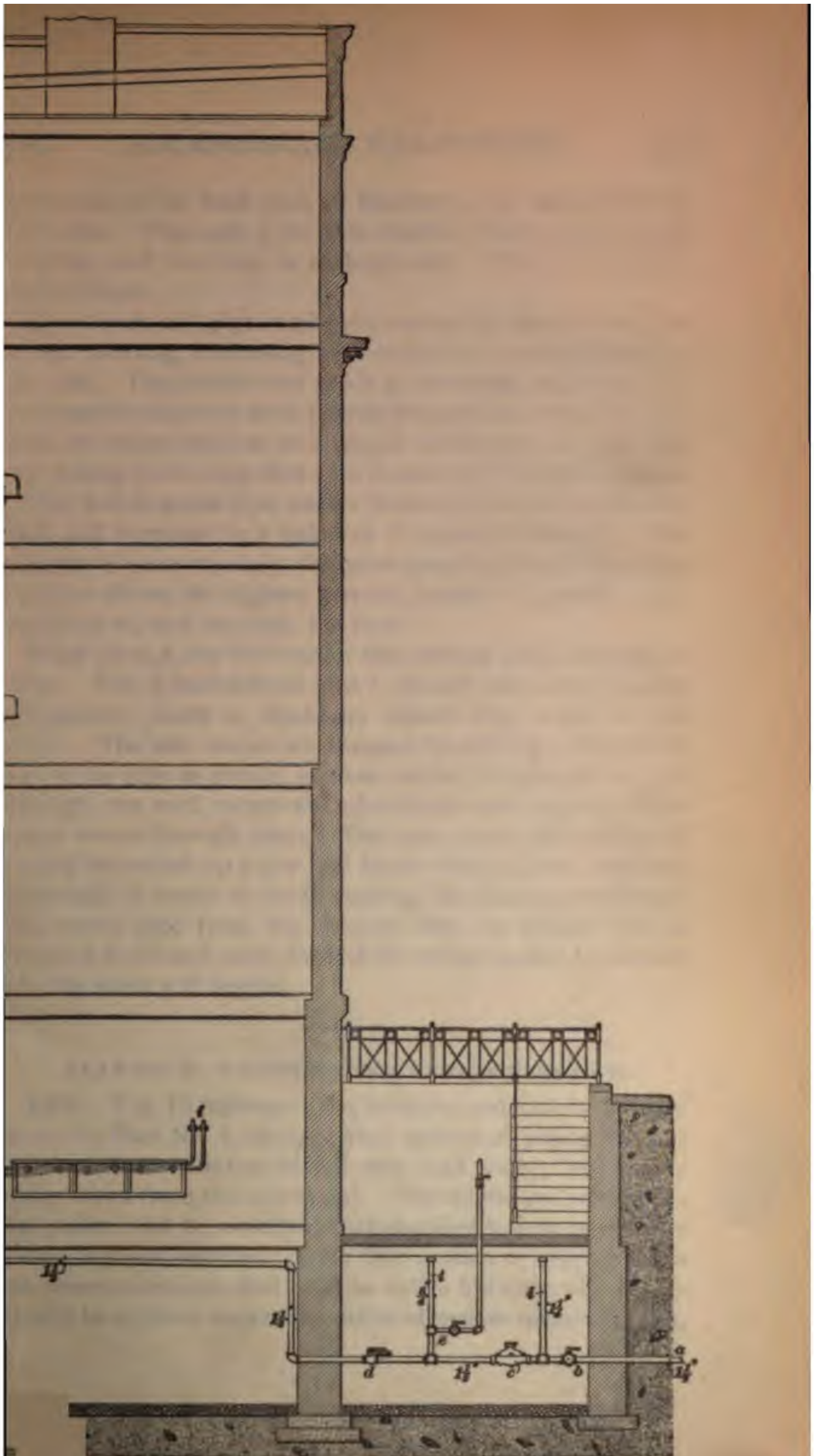
The long hopper closet *n* is fitted up in a small "lean-to"





a
b
d
e
f
t





apartment in the back area, or basement, and opens into the back area. The tank l_1 for this closet is fitted up inside the building, and the trap is underground. This is to guard against frost.

The 4-inch soil-pipe stack *p* is run up full size to the roof of the building, increasing to 5 inches as it passes through the roof. The 4-inch vent stack *q*, corresponding to *p*, also increases in diameter as it passes through the roof; its base joins the house drain at an angle of 45 degrees, so that any rust falling down may slide into *d*, and thus be washed away.

The 3-inch waste-pipe stack *r* is carried full size up to the roof, and increased to 4 inches as it passes through it. For purpose of economy only, the corresponding 2-inch vent pipe *s* joins *r* above the highest fixture, instead of passing separately up to, and through, the roof.

Brick piers p_1 are built under the vertical stacks to support them. The ½-inch telltale pipe *t*, 1¼-inch safe wastes *u*, and refrigerator waste u_1 discharge openly into a sink in the cellar. The safe wastes are trapped by making a coil on the end of the pipe as shown, and are carried full size up to, and through, the roof, to prevent odors from entering any of the upper rooms through them. The vent outlets above the roof should be carried up a few feet higher than shown; they are shortened in order to avoid making the drawing too large. The waste pipe from the Roman bath on second floor is dropped down and made to flush the urinal waste; but it may join the stack *p* if desired.

PLAN NO. 3: WATER SUPPLY, STREET PRESSURE.

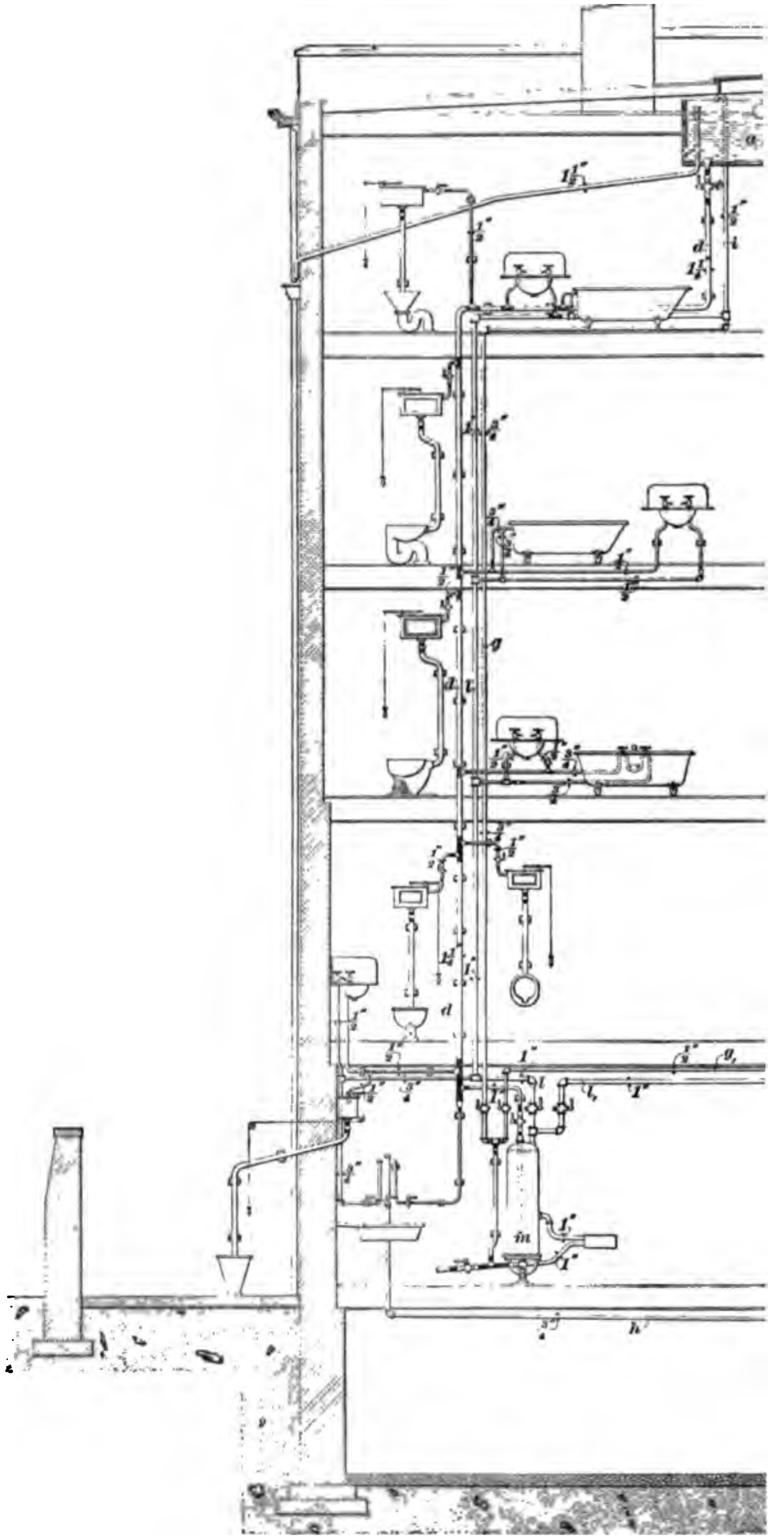
192. Fig. 73 represents the building and fixtures already shown in Plan No. 2, along with a system of piping for the supply and distribution of hot and cold water, the supply being taken from the city mains. The minimum pressure in the mains must be more than that required to just raise water to the highest fixtures. With this system of piping, when the street mains are shut off, the entire building will immediately be without water, the boiler of course remaining full,

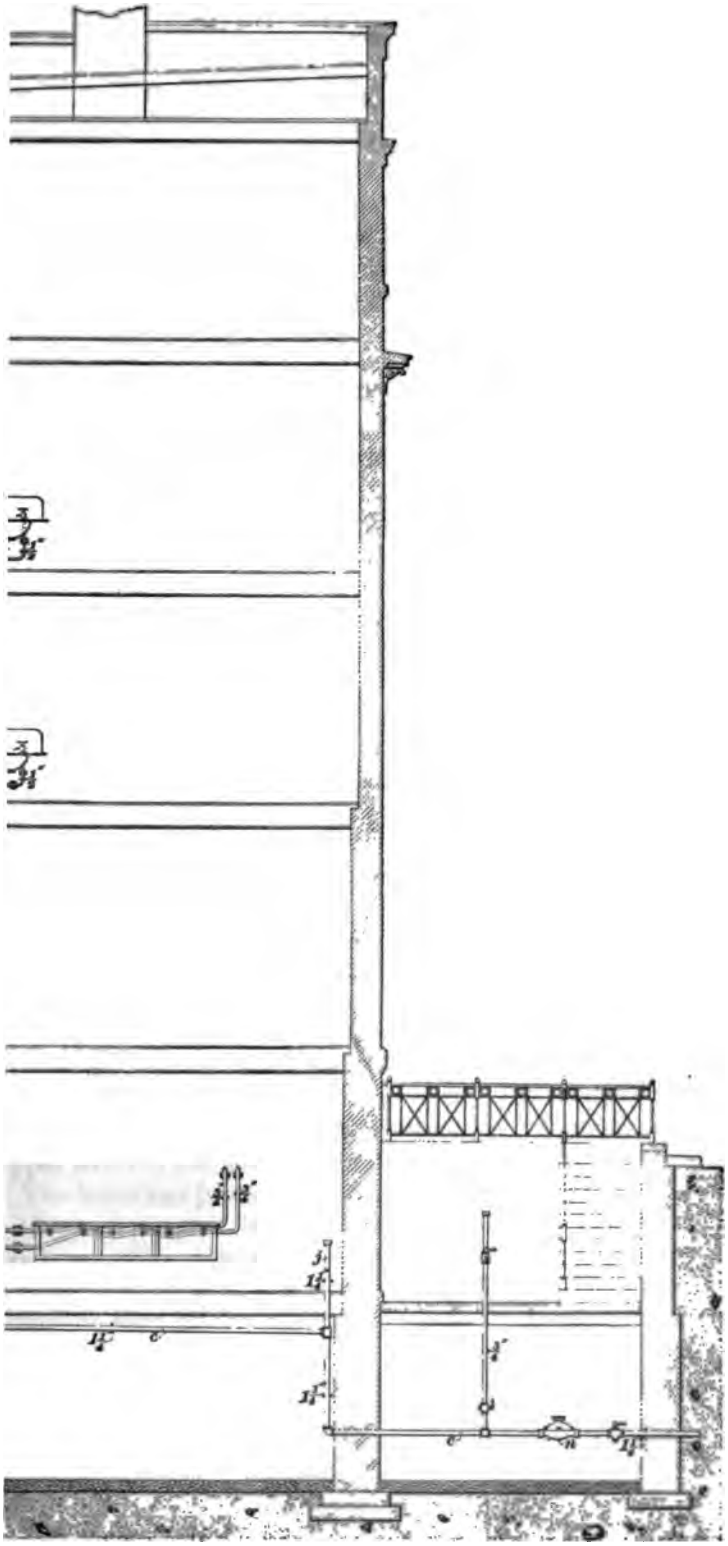
if unsiphoned. The street service pipe *a* which joins the city main to the pipes in the building has a stop and waste cock *b* attached on its end just inside the cellar. A water meter *c* fitted with an air chamber near its inlet indicates the quantity of water used in the building. The pressure in the street mains in this particular case is supposed to be too great for safety or comfort if applied to the plumbing in the building; consequently, a pressure-reducing valve *d* is placed on the house service pipe, just inside the pipe *e* which supplies a hose bibb in the front area with water under the full pressure of the main. The stop and waste cock shown on this pipe is to shut off and drain the area pipe during cold weather.

Let us suppose that the average main pressure is 95 pounds by the gauge, and that we reduce this pressure, by the use of the valve *d*, to a constant pressure of 45 pounds within the building; then the size of the pipes may be approximately as marked on the drawing. The hot and cold distributing pipes are galvanized iron or brass, and some of the branches are shown of lead.

Since the pressure-reducing valve is similar to a check-valve, a safety valve is placed upon the boiler as shown at *f*, and a pipe *g* leads any blow-off from *f* into the kitchen sink. A few lever-handle stop and waste cocks are placed upon the most important parts of the system to facilitate shutting off sections, for repairs, etc., without shutting off the entire building. Each closet tank may be shut off separately, because the ball-cocks or the tank valves in them generally require repairs more frequently than other parts of the system. The boiler and the waterback *h* furnish hot water for the entire building. It will be observed in this drawing that there is no circulation of hot water between the boiler and the fixtures, and that a considerable quantity of cold water must be drawn from some of the fixtures before the hot water flows. Air chambers *i*, *i*, etc. are attached to the piping to prevent water hammer.

The sediment pipe *j* joins the kitchen sink trap on the house side of the seal. The piping in this sketch is





exaggerated in size, and to the eye may appear out of proportion with the fixtures. This, however, was done to show the pipe connections clearly. The inside diameters of the pipes are marked on the drawing.

PLAN NO. 4: WATER SUPPLY, TANK PRESSURE.

193. In this plan, Fig. 74, the same building and the same fixtures as those in Plans Nos. 2 and 3 are shown. The fixtures are all supplied from a house tank *a* on the top floor. This tank is filled with water from a rising main *b* which joins the service pipe *c* in the cellar. If the water in the main will not rise by its pressure in the service pipe to the tank, it must be forced. This can be done by attaching a lift and force pump either to *b* or *c*.

The system shown is well adapted to cases where the water supply is intermittent, such, for example, as in towns or cities where water pressure at best is low, and where factories, mills, and other works lessen the pressure during the day to such an extent that the water cannot run to the upper floors of the building.

If the water should rise high enough at night to flow into the tank, it may do so if the ball-cock *k* is open. The tank should be large enough to hold at least a 2-day supply.

Two cold-water distributing lines d, d_1 supply cold water to the fixtures. The one to the left feeds the boiler. Stop-cocks *e* and *f*, placed on these pipes just under the tank, shut the water off the building. Circulation pipes g, g_1 run from the upper ends of the hot-water distributing pipes l, l_1 to the boiler *m*, to insure a supply of hot water at the upper fixtures the moment the faucets are opened.

The hot-water pipes shown are made of iron or brass, and the cold-water pipes of lead, except those from the main, which are iron. The pipe *h* furnishes fresh water from the main for cooking and drinking purposes. Relief pipes i, i_1, taken from the tops of the hot-water pipes, are turned over the top of the tank. To prevent a water hammer in *c* from affecting the ball-cock in the tank or in the meter *n*, a

special air chamber is attached to the main at *j*. To secure a good flow of water throughout the building, the pipes may be of the sizes given, which are the nominal internal diameters.

In this system the boiler may be smaller than in Plan No. 3, or a larger waterback may be used, because considerable heat is transmitted from the hot water while it circulates through the building. A row of lever-handle stop-cocks is arranged over the boiler for convenience in shutting off the water.

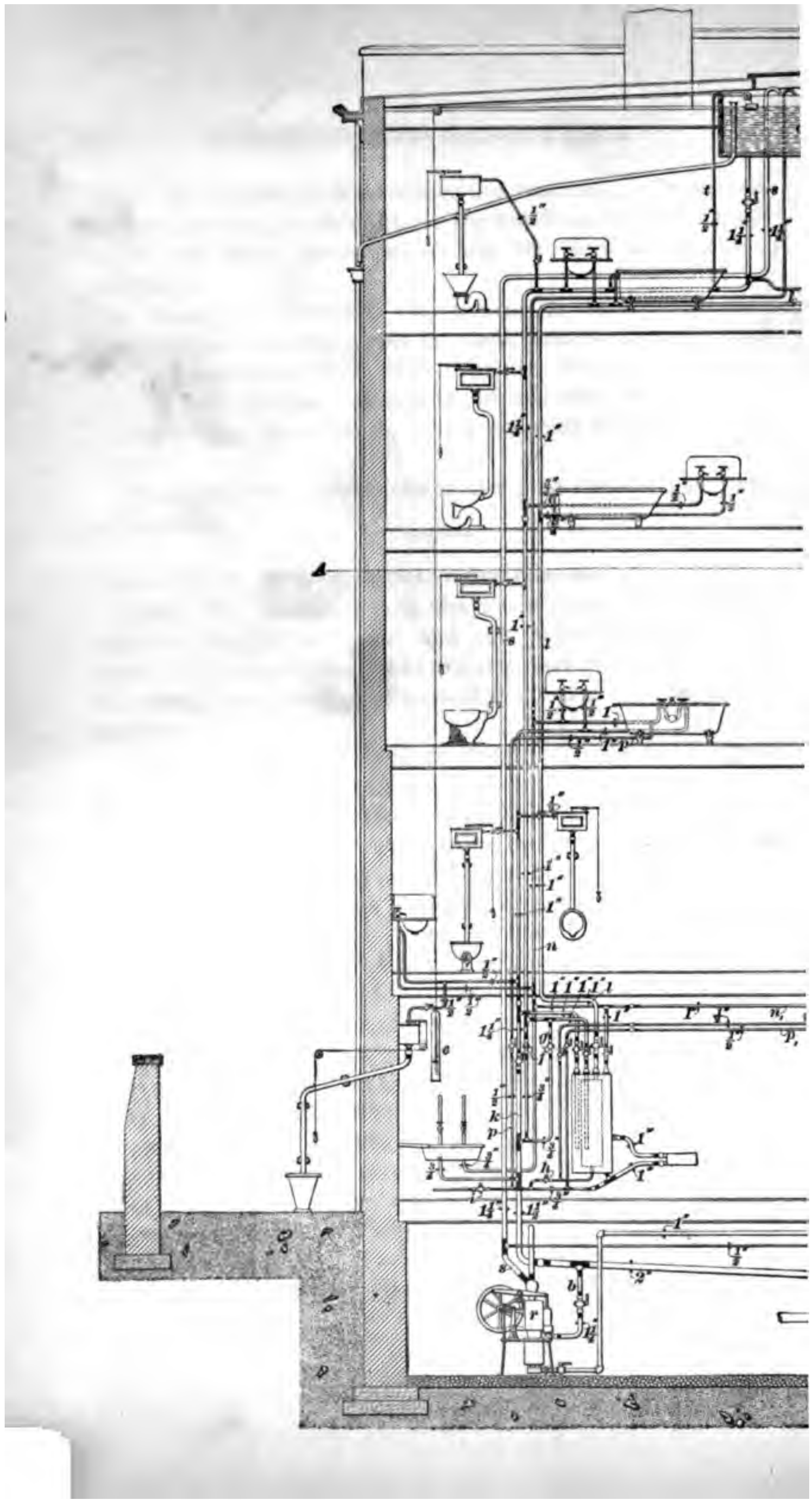
The piping and connections in this plan are also exaggerated in size.

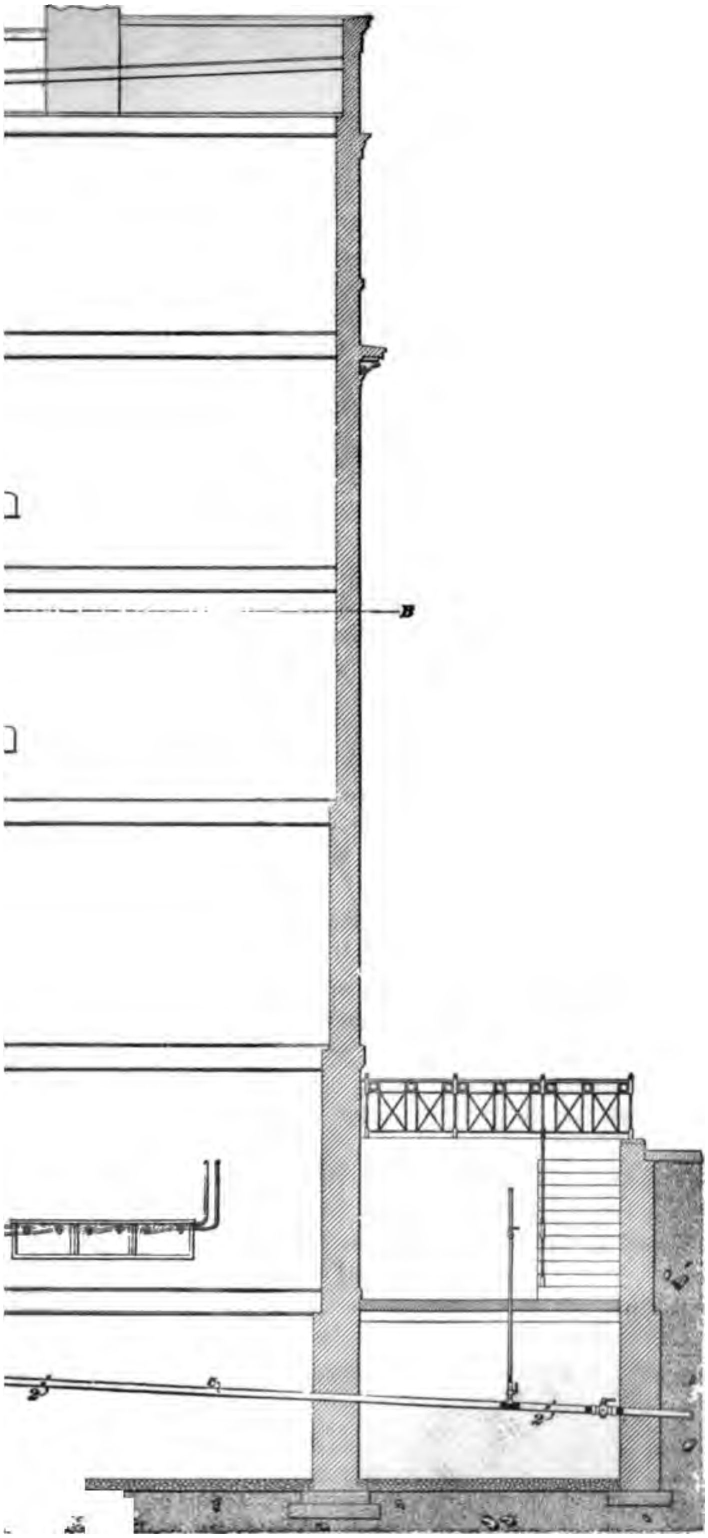
PLAN NO. 5: WATER SUPPLY, DOUBLE-BOILER SYSTEM.

194. Fig. 75 shows how the lower floors of a building may be supplied with hot and cold water from the city mains, while the upper floors are supplied from a tank, one waterback being employed to heat the water for the entire building.

The dotted line *A B* shows the height to which the street water will rise, therefore, the fixtures above that are supplied from the tank *a*. Of course, those below *A B* may also be supplied from *a*, but to economize pumping, the piping is so arranged that they can be supplied direct from the street.

An "Ericsson" hot-air pumping engine *r* is shown in the cellar, having its suction pipe *b* connected to the main *c*, and its delivery pipe *s* leading over and into the tank *a*. The engine is supplied with a gas burner, and can be stopped when the tank is full by the arrangement shown at the wheel valve *d* over the basement sink. A water-line indicator *e* is placed over the kitchen sink, so that the servants may see how much water is in the tank. This sliding indicator is attached to a float in the tank by a chain or wire, working over two pulleys. When the tank is empty, the float falls with the water and raises the indicator to the top of the slide board, and when filled again, the indicator falls towards the bottom. The slide board is graduated in feet and inches, and if the indicator is regulated properly, it will




B

indicate the depth of water in the tank very accurately. This plate also shows hot-water circulation to all the fixtures, except the kitchen sink and laundry tubs, the branches to which are short. Circulation to these fixtures may be obtained by dropping the return pipe below the boiler level, and connecting the branches to the returns. If such connections are made, however, there will be danger of hot water being drawn from the bottom of the boiler along with hot water from the flow pipes, unless check-valves are used on the returns near the boiler. Some plumbers object to check-valves on returns, and, consequently, connect these fixtures as shown.

The check-valve *f* will admit water to flow from the outer boiler or street main to the inner boiler, when the pressure in the inner boiler is less than that in the outer one, but will prevent any water in the inner boiler from passing out again.

A lever-handled stop-cock *g*, when opened, will feed the outer boiler and all the fixtures on the lower floors with tank water. Of course, when this cock is opened, the valve on the street service pipe must be closed, otherwise the tank water will flow back to the street mains. If the cock *g* be used much, a swinging check should be placed on the main service pipe *c*.

The sediment cock for the inner boiler is shown at *h*, and for the outer boiler at *i*.

The waterback is connected to the outer boiler in the ordinary manner, and heats water for the entire building. The telltale *j* flows into the pan of the automatic shut-off valve *d*, so that when the tank is full, the telltale will fill the pan with water, the weight of which will close the valve and stop the engine.

The rising main supplies cold water to the outer boiler, kitchen sink, and fixtures on first and second floors above, except the water closet on second floor, which is supplied from the tank, because it is too near *A B*.

The hot supply to third and fourth floors, or **tank hot,** flows through *l* to the top floor, where an expansion pipe is taken off its highest point and led over the tank. This pipe

then continues and drops to supply the wash basin to the right on the third floor. It is then continued back to the boiler by the return pipe *m*. The hot supply to basement and first and second floors, flows through *n* and n_1; the end of *n* being run up to and over the tank, as an expansion pipe and air vent. The pipes *p*, p_1 are for the circulation of the street hot supply. If desired, a small pipe may be run from the hot supply branch *q* to the tank to carry off any air that might accumulate there and stop circulation.

The pipe *t* acts only as a relief pipe, and may or may not be used.

In this drawing it is assumed that the street water will not at any time be sufficient to rise into the tank; otherwise, the expansion and relief pipes would be omitted, or carried considerably above the tank, to prevent the temporarily increased main pressure from forcing hot water into the tank.

The student should carefully study the different lines of pipes in the five preceding figures until he thoroughly understands the function of each pipe, and thoroughly grasps the principles of supply and distribution of hot and cold water, and the proper construction of soil, waste, vent, and drain pipe lines.

LAWS AND REGULATIONS.

195. The plumbing and drainage of buildings is regulated by law in many cities and towns. These regulations establish a standard of general excellence, to which all architects and plumbers must conform. The standard thus fixed is the lowest that will be tolerated, or that the public safety will permit. It is not the highest standard attainable, and does not aim to secure the *best* possible arrangement of drainage. The architect should carefully consider the arrangements, in every case, and should aim to supply the most perfect system of drainage and water supply that he can devise. He should not limit himself to the specific requirements of the law, but should do as much better as possible.

GAS AND GAS-FITTING.

VARIETIES OF GAS.

196. Until recent years only one kind of gas was used for illuminating and heating purposes, and that was obtained by the distillation of bituminous coal. The demand for gas for heating purposes, however, became so great, that new processes were invented, and other varieties of gas have been introduced, so that now all forms of gaseous fuel are called by the general name of *gas*.

The varieties of gas now commonly used are as follows: Coal gas, oil gas, water gas, producer gas, natural gas, gasoline gas (or carbureted air), and acetylene.

197. **Coal gas** is made by heating bituminous coal in air-tight boxes or retorts. The heat breaks up the combinations of hydrogen and carbon which exist in the natural coal, and transforms them into other compounds, most of which are gaseous at ordinary temperatures. Among the new compounds thus made are **tar**, **ammonia**, and **sulphureted hydrogen.** The tar condenses in the apparatus, and is pumped out. The ammonia is formed by the union of hydrogen with nitrogen, and has an offensive odor. Great care is taken to condense this mixture and remove it before the gas leaves the apparatus.

The worst impurity, however, is formed by the union of hydrogen with the sulphur contained in the coal. This is called sulphureted hydrogen. It is one of the vilest smelling substances known, and is very poisonous to breathe.

The odor of ordinary coal gas is due mainly to small traces of ammonia which remain in it. These impurities are removed by compelling the gas to flow in thin streams through pans filled with lime, oxide of iron, or other chemicals; or by causing it to bubble through bodies of liquid which have been charged with suitable chemicals. The former process is called **purification**, and the latter

scrubbing. The chemicals absorb the various impurities, while the gas undergoes no change, except cleansing.

198. Oil gas is made from petroleum in a similar way, or from almost any variety of animal or vegetable oil, grease, or fat. Even oily refuse and city garbage have been used successfully for the production of gas.

Good illuminating gas can also be made from wood, peat, sawdust, in fact, almost any kind of combustible material, by substantially the same process.

199. Producer gas differs from the coal gas commonly used for lighting purposes, in having much less combustible matter, and in having a large percentage of nitrogen. The average quality of producer gas contains 10 to 15 per cent. of hydrogen, and 20 to 30 per cent. of carbon monoxide. These constitute the combustible part of the gas, nitrogen forming about 40 to 60 per cent. of the total volume. This gas burns with a dull reddish flame; its value for heating purposes is about one-fourth that of an equal volume of good coal gas.

Producer gas is made by burning coal, either bituminous or anthracite, in a closed furnace with a supply of air which is purposely made too small to permit of perfect combustion. The air is usually supplied by a steam jet blower, and the amount is regulated so that it is barely sufficient to convert the carbon in the fuel into carbon monoxide, CO. The nitrogen in the air remains unchanged, and passes off into the gas pipes with the CO, as an inert, useless accompaniment, merely swelling the total volume of the product.

200. Water gas is a mixture of hydrogen and carbon monoxide, with only a very small percentage of nitrogen. It is made from anthracite coal and steam. The coal, in lumps from 2 to 3 inches in diameter, is placed in an air-tight cylinder lined with firebrick. It is ignited, and blown up to a bright incandescent heat by means of an air blast; then the blast is shut off, and a current of dry steam is blown through the mass of glowing fuel. The great heat causes the steam to break up into free oxygen and hydrogen.

The oxygen combines with the hot carbon, forming CO, and the hydrogen passes along with it, but without combining. These are then led off through suitable pipes to a gas holder. As soon as the incandescent fuel becomes a little dull or cooled, the steam is shut off, and the fire is again blown up bright with the air blast. The operations of *blowing up* and making gas are worked alternately at intervals of about five minutes, until the fuel is exhausted.

The fresh gas, as thus made, contains less carbon than good coal gas, and, consequently, will not burn with as bright a flame. It burns perfectly in heating burners, but when it is to be used for lighting purposes, it is always *enriched*, that is, made richer in carbon. This is done by vaporizing a quantity of petroleum by heat, and injecting it into the hot gas before it leaves the generator, continuing the injection until the percentage of carbon in the gas is raised to the desired standard.

Pure water gas is very light, having a density of about .4 that of air. It has very little odor, and is, therefore, more dangerous than coal gas, because a considerable leak may exist without attracting much attention. In the process of manufacture, some of the impurities are allowed to remain, so as to give the gas an odor which is plainly perceptible.

201. Water gas is also made from crude petroleum by a continuous process. This is known as **Archer gas**, from the name of the inventor of the apparatus. The oil is pumped in a small stream into a red-hot retort, where it is quickly reduced to vapor by the heat. The oil vapor is then mixed with a current of superheated steam, and the mixture is driven through a long coil of very hot pipe. The oxygen of the steam unites with the carbon of the oil, forming CO, and the hydrogen is set free. The resulting gas is permanent, and is of high value for heating purposes. It is produced at a pressure of 8 to 10 pounds per square inch.

202. **Natural gas** is obtained from holes or **wells** which are drilled in the earth. It is found in large quantities in the vicinity of deposits of petroleum; and deposits of coal,

both bituminous and anthracite, are always accompanied by greater or less quantities of gas of a very similar nature.

It is composed mainly of a compound of carbon and hydrogen, called **light carbureted hydrogen.** This often amounts to 90 per cent. or more of the total volume. Consequently, the gas will develop more heat per cubic foot in burning than any other kind of gas except acetylene.

Natural gas is produced at the wells under great pressure, and in common practice, the pressure in the street mains and distributing pipes is allowed to be very much higher than is usual with manufactured gas.

203. Acetylene is a compound of carbon and hydrogen. Its chemical symbol is C_2H_2, and its composition is 12 parts of carbon to 1 of hydrogen by weight, or 92.3 per cent. carbon and 7.7 per cent. hydrogen. The proportion of carbon is extraordinary, and the compound appears to be overloaded. It is known to be unstable, and the gas is liable to decompose spontaneously and explosively, under the action of a violent shock or blow. There is, therefore, some danger in handling and using it.

Its density compared with that of the air is .91, and its weight at 32° F. is .073 pound per cubic foot. It is without perceptible color, and it has a strong odor like garlic. It is poisonous to breathe, in about the same degree as ordinary illuminating gas.

The heat which it is capable of developing by burning is theoretically 1,090 heat units per cubic foot.

Acetylene is manufactured by an indirect process, no direct process, suitable for common use, being at present known. The first step in the process is to form a compound of carbon with calcium. This is done by subjecting a mixture of coke and lime to the intense heat of an electric furnace. The product, which is called **carbide of calcium,** is a reddish-brown or gray material, opaque, somewhat crystalline, and it decomposes water like ordinary quicklime.

When it is desired to produce acetylene, the carbide of calcium is put into water. Both materials decompose. The

calcium takes up oxygen from the water, forming oxide of calcium, which is common quicklime. The carbon combines with the hydrogen of the water and forms the desired compound—acetylene. Considerable heat is given off during the operation.

Pure carbide of calcium will yield 5.4 cubic feet of acetylene per pound; but the commercial material is impure, and gives in practice $4\frac{1}{4}$ to $4\frac{3}{4}$ cubic feet per pound, at atmospheric pressure.

204. Acetylene gas, when burned in ordinary Batswing burners, gives a dull, smoky flame, because the gas is not spread out sufficiently to secure from the air the oxygen required to burn the carbon properly.

To develop the full illuminating power of the gas, it is necessary to greatly enlarge the flame. This may be done by using a burner tip having the thinnest slit obtainable, and by giving the gas a heavy pressure—4 or 5 inches of water or more.

One valuable quality of acetylene is its ability to furnish lights of very small size, but of great brilliancy. With a properly made burner, a light about $\frac{1}{8}$ inch in diameter can be made which will give the same illumination as an ordinary candle.

Carefully made tests show that acetylene will give a light of 240 candlepower, when burned at the rate of 5 cubic feet per hour; while good, ordinary illuminating gas will average about 16 candlepower at the same rate of consumption.

A flame giving a light of 20 candlepower will consume about $\frac{1}{2}$ cubic foot of acetylene per hour; but to obtain this result, great care must be taken in the construction of the burner.

Acetylene can be reduced to liquid form, at a temperature of 60°, by a pressure of about 600 pounds per square inch; and it can then be stored in portable steel cylinders like other gases.

It corrodes silver and copper, and the compounds thus formed are explosive. It does not affect brass, iron, lead, tin, or zinc. These facts should be borne in mind when constructing apparatus for its use.

205. **Gasoline gas** or **carbureted air**, also called **air gas**, is a mixture of gasoline vapor with air. The pure

vapor is so rich in carbon that, in order to burn it successfully for lighting purposes, it must be given a high pressure; and special burners must be employed, as for acetylene.

The pure gasoline vapor contains a much greater amount of carbon per cubic foot than ordinary illuminating gas; and in order to burn it in the same burners and at the same pressure, it must be *diluted* with air until the proportion of carbon equals that in ordinary coal gas.

The air furnishes a part of the oxygen required for combustion, but it also introduces a large proportion of nitrogen, which is an inert and useless material, being incombustible; and it operates to reduce the temperature of the flame and thus to diminish its brilliancy.

Gasoline is produced by distilling crude petroleum. Its specific gravity is about .74 that of water. It is really a mixture of a large number of hydrocarbon compounds, which differ slightly in their chemical proportions. All of them, however, will change from the liquid to the gaseous form, under ordinary atmospheric pressure, at a temperature ranging from 70° to 100°. If a tank containing liquid gasoline be opened to the air, the liquid will all pass away in the form of gas. The rapidity of the evaporation will depend upon the temperature, being very slow at 40°, quite rapid at 70°, and furious at 212°; and, if the liquid catches fire in any way, it will pass into gas with explosive violence. The burning liquid expands enormously and is very difficult to extinguish. Gasoline must be regarded as gas in a liquid form, and it should be clearly understood that it will resume the gaseous form whenever the opportunity is afforded.

It is generally regarded as a dangerous material to use or handle, but the danger arises from the recklessness or neglect of the persons using it. If the same care is taken to keep it shut up as is taken to keep coal gas confined, it is no more dangerous than the latter. A tank of gasoline should be treated as a *reservoir of gas.*

206. Gasoline is put upon the market in several grades. The highest grade, sometimes called **winter gasoline,** will

evaporate at ordinary temperatures and leave nothing behind. The poorer grades contain more or less oil which will not evaporate without the aid of heat; this oil collects in the gas-generating apparatus, and must be removed from time to time.

The quantity of gasoline which is required to produce 1,000 cubic feet of gas, and which will give a light of 14 to 16 candles (when burning at the rate of 5 cubic feet per hour), is about 4½ gallons of the best grade, but more is required, if the gasoline is of a lower grade.

GAS MEASUREMENT.

207. Gas is measured for pressure and for volume. The **pressure** of gas is usually measured by a water gauge, and the reading is taken in inches of water, which represents the vertical height of a column of water which the gas pressure can sustain. This is the pressure of the gas above that of the atmosphere; it is really the *working pressure*, and not the *absolute pressure*.

The common **water gauge** is shown in Fig. 76. The tube *a* is made of metal, and is provided with a socket *d* which will screw on to an ordinary fixture in the place of a burner. The tubes *b* and *c* are made of glass, and are filled with water up to the zero of the scale. The scale is graduated in inches and convenient fractions of an inch. The tube *c* is open to the air at the top. When pressure is admitted to the tube *a*, the water will sink in the tube *b*, and will rise in *c*. The difference in the height of the water in the two tubes, measured in inches, is the measure of the pressure exerted in *inches of water*. The depression below zero in *b* should be added to the rise above zero in *c*. The fall in one tube will not exactly equal the rise in the other, unless the tubes are of exactly equal bore.

FIG. 76.

For measuring heavy pressures, mercury may be used in the tubes, instead of water.

208. Pressures which have been measured in inches of water or mercury, may be translated into pounds per square inch or square foot, by multiplying the reading by the following figures:

One inch of water at 62° = 5.2 lb. per square foot.

One inch of water at 62° = .0361 lb. per square inch.

One inch of mercury at 62° = .4897 lb. per square inch.

Pressures per square inch or square foot may be converted into inches or feet of water, or inches of mercury, by multiplying the pressures by the following figures:

One pound per square foot = .1923 inch of water at 62°.

One pound per square inch = 27.7 inches of water at 62°.

One pound per square inch = 2.042 inches of mercury at 62°.

209. If the specific gravity of a gas is less than that of air at the same temperature, then the pressure will always be greatest at the top of the pipe or chamber which contains the gas. If the gas is heavier than air, then the greatest pressure will be at the bottom of the chamber which contains it.

The upward pressure of gas having a less density than air, is caused by the deficiency in its weight and its consequent inability to balance the pressure of the atmosphere.

The **increase of pressure** in each 10 feet of rise in pipes with gas of various densities, is as follows:

TABLE 9.

Rise in pressure (Inches of Water)	0	.0147	.0293	.044	.058	.073	.088	.102
Density of gas	1	.9	.8	.7	.6	.5	.4	.3

EXAMPLE.—The pressure in the basement, at the meter, is 1.2 inches of water; what will be the pressure at the sixth story, 70 feet above, the density of the gas being .4 ?

Solution.—The table shows that the increase will be .088 inch for each 10 feet of rise, therefore, $.088 \times 7 = .616$ inch increase. Then, pressure at sixth story $= 1.2 + .616 = 1.816$ in. Ans.

210. To measure the **volume** of **gas** passing through a large pipe, it is necessary, first, to determine the *velocity* by means of a *Pitot tube*, or some other suitable instrument, and then ***multiply the mean velocity by the sectional area of the pipe.***

For ordinary purposes, however, the volume of gas passing through a pipe is measured by an apparatus called a **gas meter.** A gas meter measures the *volume* only, and its indications are not affected by any change that may occur in the pressure of the gas. Gas is used at the burners at a nearly uniform low pressure, while the pressure in the street mains often varies 3 or 4 inches per day. Consequently, a gas meter is a very inaccurate instrument for measuring the actual *quantity* of gas supplied.

Usually the gas meter is adjusted to measure correctly *at a certain pressure*, and that pressure is intended to be the *average* pressure of the gas in the mains in the locality where the meter is used. Although the mechanism of the meter may be perfectly accurate, yet if the pressure for which it is adjusted does not correspond with the *actual* average pressure in the mains, it will necessarily give incorrect measurement.

PIPING BUILDINGS.

211. The main supply pipes which are laid in the streets are called **mains.** They are made of cast iron.

The branches which conduct gas from the mains to the house are called **service pipes** or **services.** They are usually made of cast iron or wrought iron.

The pipes which convey the gas from the meter to the various parts of the building are called **distributing pipes.**

All vertical pipes are distinguished as **risers** or **drop pipes,** according to the direction of the flow of gas within them. The flow is upwards in a *riser*, and downwards in a

drop pipe. All of the piping inside a building is usually plain wrought iron, with screwed joints.

212. Size of Pipes.—The capacity of each pipe must be great enough to supply all of the burners which receive gas through it, when every burner is in full operation. Allowance must also be made for all heating and cooking apparatus, not only for that which is decided upon, but for all that is liable to be required.

Service pipes should never be less than $\frac{3}{4}$ inch in diameter, because of the liability to chokage, and it is advisable to make the diameter at least 1 inch if the pipe is of iron. For small cook stoves, the supply pipe should be at least $\frac{3}{4}$ inch in diameter, and larger stoves should have pipes 1 to $1\frac{1}{2}$ inches in diameter.

In computing the quantity of gas required for lighting purposes, one *burner* may be reckoned as consuming 5 cubic feet of gas per hour, unless otherwise stated in the specifications. The quantity actually required by burners of modern and improved construction, however, differs so much from that of the common forms, that it is impracticable to compute the volume of gas required by merely noting the number of burners.

Having ascertained the probable maximum quantity of gas required in cubic feet per hour, the necessary diameter of the pipe can be found from Table 10. If the length of the proposed pipe exceeds the maximum length given in the table, then the diameter chosen should be the next size larger. If the pressure of gas exceeds 2 inches of water, the principal pipes may be reduced in diameter one size. If the pressure is less than 1 inch of water, then all the pipes must be made one size larger, and in case of very long pipes, the diameter will require to be increased still more.

The pressure of the gas is assumed in the accompanying table to be about 2 inches of water. It should be understood that the quantities given are those which the pipes will deliver at the burners *without objectionable fall of pressure*.

TABLE 10.

CAPACITY OF WROUGHT-IRON GAS PIPES.

Diameter of Pipe. Inches.	Maximum Length. Feet.	Capacity per Hour.	
		Coal Gas. Cubic Feet.	Gasoline Gas. Cubic Feet.
$\frac{1}{4}$	6	10	
$\frac{3}{8}$	20	15	10
$\frac{1}{2}$	30	30	20
$\frac{3}{4}$	50	100	75
1	70	175	125
$1\frac{1}{4}$	100	300	200
$1\frac{1}{2}$	150	500	350
2	200	1,000	700
$2\frac{1}{2}$	300	1,500	1,100
3	450	2,250	1,500
4	600	3,750	2,500

213. The use of the table is shown in the following example:

EXAMPLE.—What diameter of pipe should be used to supply three ordinary burners, the length being 60 feet?

SOLUTION.—The quantity consumed will be $3 \times 5 = 15$ cubic feet per hour. The table shows that $\frac{3}{8}$-inch pipe can be depended upon to deliver that quantity of gas at a distance of 20 feet only, therefore, it will not serve properly to carry 60 feet. The $\frac{3}{4}$-inch pipe is evidently too large, therefore, the intermediate size—$\frac{1}{2}$ inch in diameter—may be used. Ans.

When carbureted air, or gasoline gas, is used, no distributing pipe should be less than $\frac{3}{8}$ inch in diameter.

214. Drainage of Pipes.—Illuminating gas nearly always contains a small percentage of watery vapor, and this condenses upon the interior of the pipe. The condensed water will flow to the lowest point in the pipe, and if no provision is made for its removal, it will accumulate to such an extent as to close the passage and stop the flow of gas.

Therefore, all horizontal pipes, unless very short, must be so inclined that they will drain properly. All the branches of a riser must be inclined to drain back into it, or, if the branch be very long, it may be inclined so as to drain into a drip cup at some intermediate point. Usually the whole system of house pipes is arranged to drain back into a **drip cup,** or **siphon,** at the meter.

Drip cups must always be located at some point where they can be got at and emptied without difficulty.

Gas pipes composed of lead or other soft metal must be guarded against *sagging* by running them upon a ledge or shelf. Every sag operates as a pocket to collect water, and if the depression of one of the sags equals the diameter of the pipe, the accumulation of water will eventually choke the pipe and stop the flow of gas.

215. All gas-pipe **fittings** smaller than 2-inch should be made of galvanized malleable iron reinforced with heavy beads around the screwed sockets. Larger sizes may be made of cast iron.

Elbows, **T**'s, and other fittings should stand clear from the studding and joist, whenever practicable, so that all of the joints may be accessible for the purpose of testing.

Changes in the direction of small pipes should be made by bending the tube, if practicable, instead of using an elbow. Elbows and other fittings, to which side lights or brackets are attached, should be provided with flanges or lugs, and should be firmly secured with screws to solid woodwork, or, in case of brick walls, to wooden plugs driven into holes drilled in the wall, or to wooden blocks embedded in the wall for that purpose, so that the fixture will not wabble.

The nipple for a side light or bracket should project from the wall at a true right angle to a distance of not less than $\frac{3}{4}$ inch, and not more than $1\frac{1}{4}$ inches. The nipple should be screwed tightly into the fitting, and a cap should be screwed on the outer end of it. This cap should be screwed up with only a moderate force, so that it can be easily removed at any time without danger of loosening the nipple from the fitting.

Drop nipples, which are to support chandeliers or other hanging fixtures, should hang perfectly plumb, and in case of a flat ceiling should project from $\frac{3}{4}$ inch to $1\frac{1}{4}$ inches from the surface.

216. The proper mode of supporting a hanging fixture is shown in Fig. 77. The weight of the fixture is carried by the wooden block *a*, which must be made strong and be well secured to the joists *b*, *b*. The lower block *c* serves to guide the

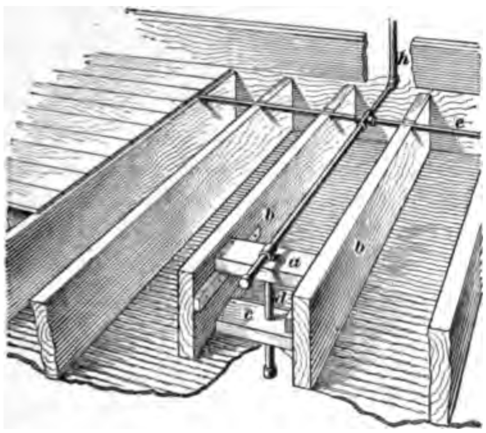


FIG. 77.

drop piece *d* and prevent it from swinging in any direction. Care should be taken to make the drop piece perfectly plumb.

When the nipples or drops for the fixtures are all in place, they should be tested to find whether they are square or plumb. This may be done by attaching a straight piece of pipe a foot or so long to which the square and level may be applied, or a plumb-bob may be used.

217. The gas pipes should be placed in a new building as soon as the walls are up and the rough timbers of the floors and partitions set, but before the floors are laid or the lathing done. When a gas pipe runs parallel with the floor boards, as shown at *e* in Fig. 77, the board which covers it should have the lower flange of the groove removed, so that it can be readily taken up when desired. If the pipe runs crossways of the floor boards, a loose piece should be provided in

the floor over every principal elbow or **T**, so that they can be got at easily in case of repairs or leakage. The loose boards and covers should be fastened in place with $2\frac{1}{4}$-inch screws. Brass screws are frequently used for that purpose, as they will not rust.

GAS-FITTERS' PLANS.

218. The location of gas fixtures is generally indicated by a star, thus *, and the number of burners on each fixture, together with the height of the fixture above the floor, is usually stated in the specifications.

To facilitate the work of running the pipes and of estimating their proper sizes, plans should be made of the piping on each floor. On these should be noted the position of each fixture, its height from the floor, and the number of burners required for each.

The number of burners and the kind of fixture may be conveniently indicated by the symbols shown in Fig. 78. *A*, *B*, and *C* represent side lights or brackets having 1, 2, and

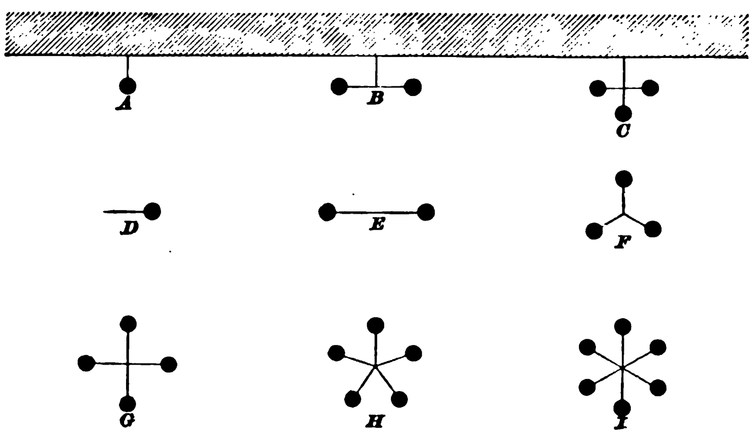


FIG. 78.

3 lights, respectively, each large dot representing a burner. In a similar manner, *D*, *E*, *F*, *G*, *H*, and *I* represent drop lights having 1, 2, 3, 4, 5, and 6 burners, respectively. The manner of using these symbols is exemplified by the plans, Figs. 80 and 81.

219. The horizontal piping should be indicated by plain black lines, and each floor plan should show only those pipes which are to be actually run in the floor of that story, or upon the under side of it.

The points at which risers or drop pipes are to be connected to the horizontal pipes should be indicated as shown in Fig. 79. Thus, an × at *j* indicates that a drop pipe descends

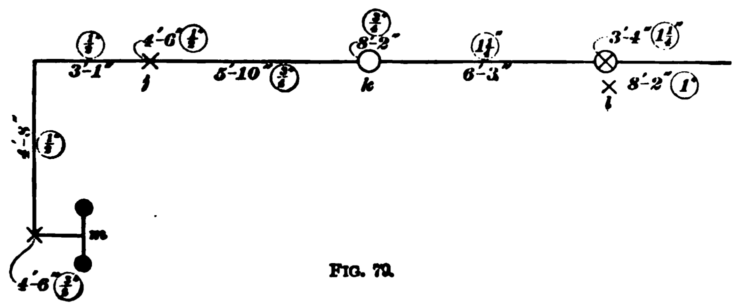


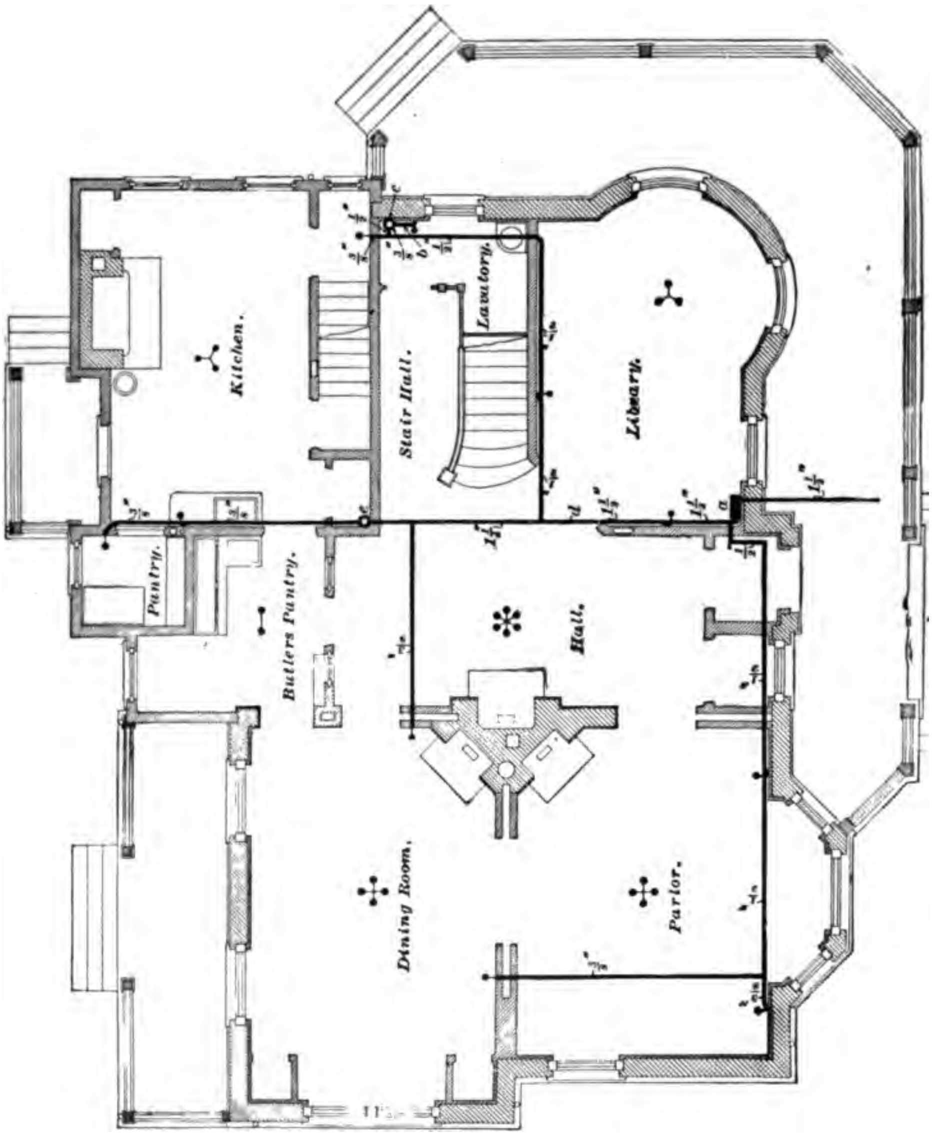
FIG. 79.

from that point, and a O at *k* indicates that a riser ascends from that point. The symbols O and × combined as at *l*, indicate that the vertical pipe extends both above and below. At *m* is indicated a drop pipe leading to a bracket or side light having two burners.

If the lineal measurements are to be embraced in the plans, the length of each pipe should be figured from center to center of fittings, and the diameter should be written close to the figures indicating the length. Thus, the pipe between *l* and *k* is shown to be $1\frac{1}{4}$ inches in diameter and 6 feet 3 inches between centers of fittings.

The length of each riser or drop pipe should similarly be indicated by figures placed near the symbol, and connected to it by a light line; thus, at *j* we have a drop pipe $\frac{1}{2}$ inch in diameter, descending 4 feet 6 inches to center of fitting; at *k* we have a riser $\frac{3}{4}$ inch in diameter, ascending 8 feet 2 inches; at *l* we have a riser $1\frac{1}{4}$ inches in diameter, ascending 3 feet 4 inches, and a drop pipe 1 inch in diameter, descending 8 feet 2 inches.

In order to show which figures belong to the drop pipe at *l*, it is necessary to place an × before them, as shown. Where


Kitchen.
Stair Hall.
Lavatory.
Library.
Pantry.
Butlers Pantry.
Hall.
Dining Room.
Parlor.

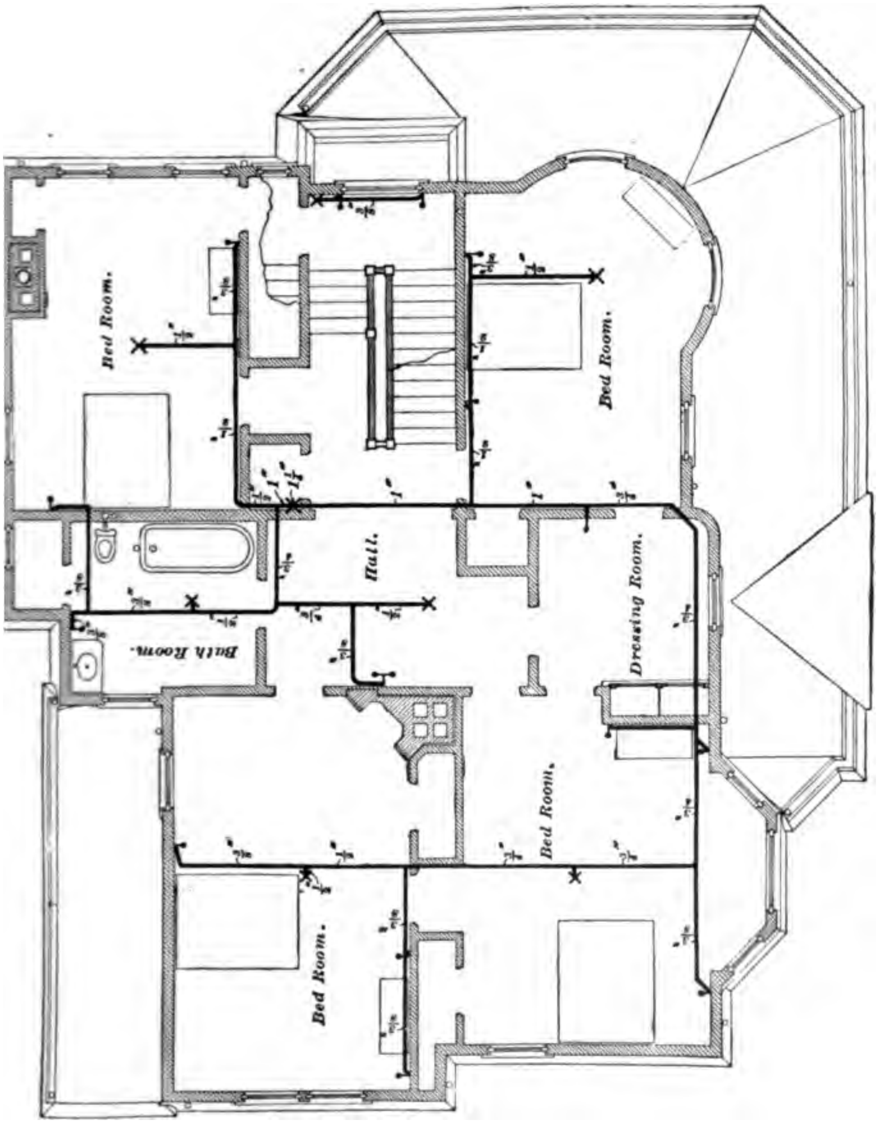

Bed Room.
Bed Room.
Hall.
Bath Room.
Dressing Room.
Bed Room.
Bed Room.

FIG. 51.

figures are crowded, it is advisable to draw a O around the figures indicating diameters of pipes, in order to clearly distinguish them from all others.

If any of the vertical pipes require to be offset or bent to pass around obstructions, etc., or a horizontal pipe requires to be run along a wall at a height between the floor and the ceiling, a reference letter should be placed conspicuously at that point, and a corresponding note made upon the margin of the drawing. A diagram of the special pipe required should be made and attached to the drawing.

Gas-fitters' plans are sometimes made in perspective; but if the work is at all complicated, the drawing is likely to be very confusing, especially if the draftsman is a little unskilful.

The plan recommended above has the advantage that several sets of piping for various purposes may be indicated upon the same drawing. Thus, pipes for gas, steam, and water, and tubing for electric wires, may be shown by using differently colored inks for the various systems of pipe.

220. Fig. 80 shows the first-floor plan of a common two-story and basement dwelling house. The second-story plan is shown in Fig. 81. These figures are supposed to represent tracings from the general drawings with the gas piping drawn in.

The meter *a* is placed in the basement, and all the piping shown on this plan is run along or under the basement ceiling, except *b*, which is a $\frac{3}{8}$-inch horizontal branch to supply the lavatory bracket from a $\frac{3}{8}$-inch riser *c*, run from the basement to the brackets on the stair landing above. A distributing main *d* runs directly from the meter outlet to the riser *e*, and all the branches which supply gas to the brackets of the first floor, also the basement lights, are taken from this pipe.

The chandeliers or pendants which illumine this floor are supplied with gas from the pipes shown in Fig. 81. These pipes run under the floors and across or between the joists. They also supply all brackets which illumine the second floor.

The pipes are proportioned to give an abundant supply of gas to the entire building when all the jets are burning at

the same time. They are also all laid to pitch back towards the meter, where a drip cup may be placed. The piping in Fig. 81 is so arranged that no floor joists will be cut at a greater distance than 2 feet from a point of support. The joists all run from front to rear of the building.

There are many other ways of running the pipes for this work, but the drawings show a method probably as good as any.

221. In selecting the **location** of the pipes, the architect should be governed by the following considerations:

1. The pipes should run to the fixtures in the most *direct* manner practicable.

2. The pipes must be *graded* to secure proper drainage without excessive cutting of floorbeams, or otherwise damaging the building.

3. Pipes which run across the floorbeams should be laid not more than one foot away from the wall, so as to avoid serious injury to the floor by the cutting of beams near the middle of their span.

4. Fixtures should be supplied by risers, rather than by drop pipes, as far as practicable.

5. All pipes should be located where they are accessible for repairs with the least possible damage to the floors or walls.

222. Service-pipe connections should be made to the top of the street main. The pipe should be inclined so that it will drain into the main, but if this is not possible, it should be inclined toward the building, and should be provided with a suitable drip cup, from which water may be conveniently drawn off.

A shut-off cock should be placed in every service pipe at the curb, and this should be enclosed in a suitable box extending upwards to the surface of the pavement, and closed against the entrance of dirt, water, or snow by a tight cover.

223. Meter connections to service pipes, and also to the house pipes, should be made with lead pipe so that they will bend and relieve the couplings on the meter from injurious strains. The meters are usually furnished and set in place by the gas company.

224. Gas pipes should not be *exposed to the weather*, if possible to avoid it, and care must be taken to protect them from freezing winds, or air-currents. The moisture will condense upon the interior of the pipe and form ice, and the deposit will increase in thickness until the pipe becomes choked. Exposed pipes should be covered with hair felt or other good non-conducting material, which should be made thoroughly waterproof by a covering of painted canvas. Good protection is especially necessary if the pipe contains carbureted air or gasoline gas.

Iron gas pipes should not be allowed to touch lead pipes or electric wires which run across or near them, because the continual shifting caused by changes in temperature will ultimately wear a groove or thin spot in the softer pipe, and the insulation of the electric wire will be cut through, thus making a *ground* or *short circuit*.

If a metal pipe runs within two inches of an electric wire, they should be separated by a non-conductor of some description. For example, the pipe may be wrapped with four or five layers of rubber tape.

TESTING A SYSTEM OF PIPES.

225. As soon as the pipes are all in place and are properly secured, the system should be tested to find whether it is perfectly gas-tight. The instruments required for making the test are a pump and a mercury gauge.

Air should be forced into the pipe system until the gauge indicates 15 or 20 inches of mercury, or 7 to 10 pounds per square inch. The pump should then be shut off, leaving the gauge under pressure. The pressure should be continued in the pipes for about an hour, and if the gauge shows a falling off in pressure of more than one-half inch of mercury, or one-quarter of a pound per square inch, then the system cannot be passed as perfect.

The extent of the leak may be judged by the rapidity of the fall in pressure, but its location must be found by the sense of smell. For this purpose, a small quantity of ether should be introduced into the pipes. The odor of the ether

will diffuse throughout the system of piping and will escape from the leak, thus revealing its location.

If any fittings are cracked, they should in all cases be removed. Cracked or split pipes should always be removed; it is useless to try to patch them. No patched or cemented pipes or fittings should be allowed to pass.

In case of large buildings, it is advisable to test the piping in sections, say one floor at a time, since in this way it is much easier to locate leaks. After each section is tested, they may be connected, and then subjected to a final test.

The pipes should not be covered until the tests are completed. Usually the gas companies or the city authorities require that the testing be done in the presence of their inspector. If no such regulations are in force, then the owner or architect should witness the tests, so as to avoid any possible disputes.

GAS BURNERS FOR LIGHTING PURPOSES.

226. The common **fishtail,** or **union jet,** burner is shown in Fig. 82. The gas issues from the orifices shown,

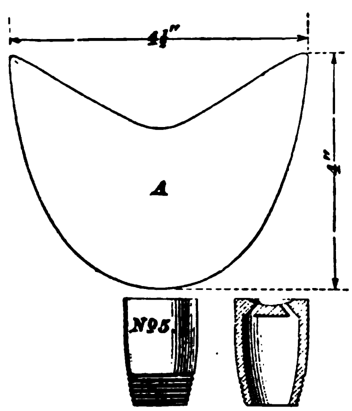


FIG. 82.

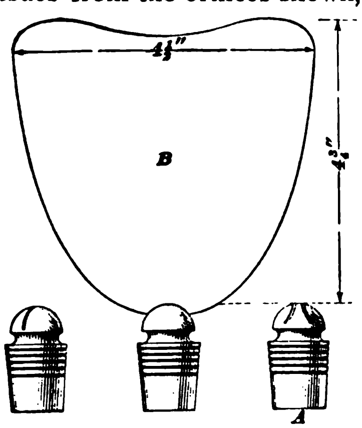


FIG. 83.

in two round jets, which collide and spread out into a flat two-pointed flame, of the general shape shown at *A*.

227. The **Batswing** burner is shown in Fig. 83. The head of the tip is hemispherical, and the gas issues through

a single straight slit which spreads out into a thin flat sheet of flame, of the general shape shown at *B*.

The capacity of these burners, in cubic feet of gas per hour, is marked either by figures stamped upon them, or by means of rings cut around them—one ring for each cubic foot. These marks serve to show the capacity only in the most general way, and cannot be relied upon for accuracy.

228. The **Argand** burner, shown in Fig. 84, consists of a hollow ring *a*, which is attached by two hollow arms *b* to a socket *c*, which is threaded to screw on an ordinary burner nipple. The gas issues from the interior of the ring through a series of small holes *d*, and the jets all unite to form a complete circle of flame. A plentiful supply of air passes up through perforations in the chimney holder *e* and also through the central hole of the burner. The volume of the gas is regulated by a screw *g*, which has a very coarse pitch, requiring only about one-third of a revolution to nearly close the valve *h*.

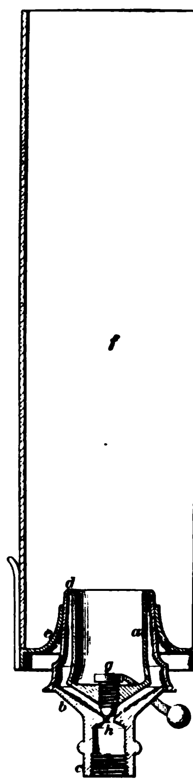


FIG. 84.

In order to secure the best results with this burner, the pressure should be about .2 inch of water, and the chimney *f* must be of such diameter and length that the draft will supply the proper amount of air to completely burn the gas—no more or less. This amount will vary somewhat with different qualities of gas.

Every Argand burner should have a volumetric regulator. Without it, they are liable to be wasteful, while if they are properly regulated and adjusted, they will burn gas very economically.

Compound Argand burners have two or more burner rings.

229. The **regenerative** lamp, or burner, is made in many ways, but the object in every case is to heat the air or the gas, or both, before the gas is burned.

The simplest application of the *regenerative* principle is shown in Fig. 85. Two or more small Batswing burners are supplied by a pipe which descends close to the flames and which is heated by them. The gas is thus heated before it is burned, and the temperature of the flame is augmented accordingly. Even this crude application of the principle of regeneration produces a perceptible increase in the brilliancy of the lights.

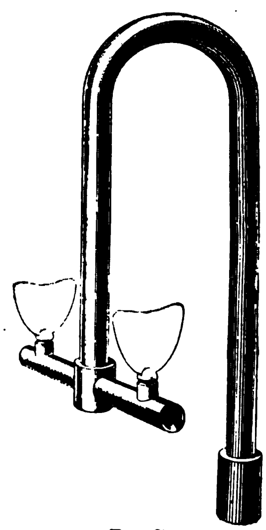


FIG. 85.

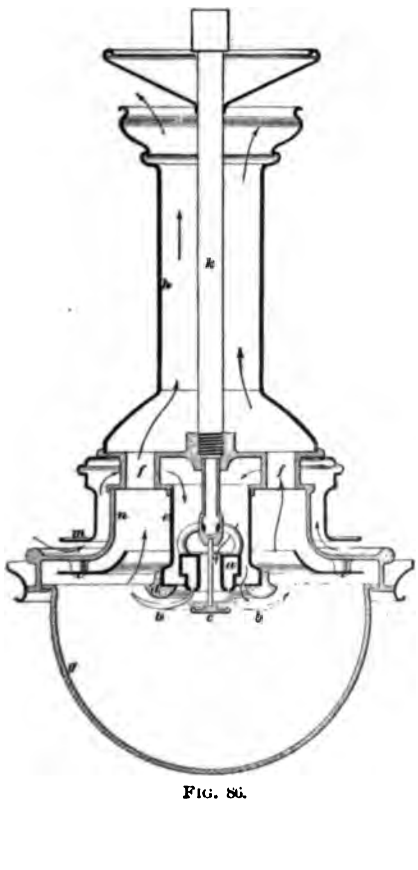


FIG. 86.

230. In the **Wenham** lamp, shown in Fig. 86, both the air and gas are heated before combustion. The burner *a* is an ordinary Argand ring inverted; that is, having the jets of flame upon the bottom end. The flames *b* are turned outwards by a deflector *c*, and they curve over the rounded surface of porcelain rings

d, thus forming a broad horizontal ring of flame of great brilliancy. The lamp is closed tightly against the entrance of air below the flame by means of the glass hemisphere *g*. The hot products of combustion pass upwards around the tube *e* through a number of tubes *f*, and up the chimney *h*. The gas passing down the tube *k* is highly heated before it reaches the burner. The air required for combustion enters between the cap *m* and the shell *n*, passes between the hot tubes *f*, and thence downwards through the tube *e* to the Argand burner. This construction is said to increase the amount of light given off from three to four times above that produced by good Batswing burners using the same quantity of gas.

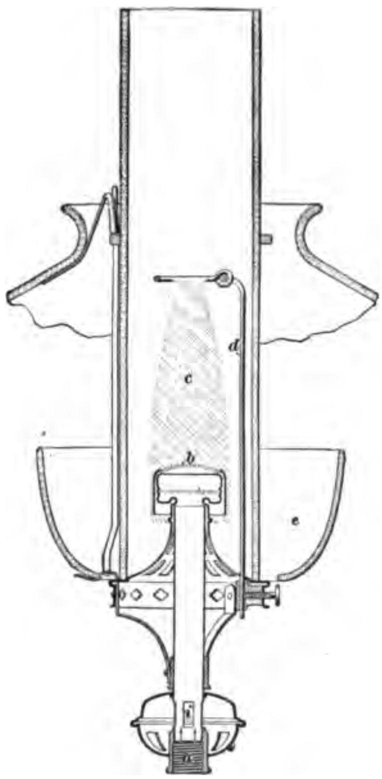


FIG. 87.

231. The **incandescent** lamp is made in various ways by different inventors, but all of them operate on the same general plan. The **Welsbach** lamp, shown in Fig. 87, is a good representative of the class. The burner is of the ordinary Bunsen variety (see Art. **234**); the gas enters at *a* and the air at *i*. The mixture burns on the top of the wire gauze cover *b*, producing great heat and but little light. This heat is transformed into light by means of a hollow tubular network *c*, which is suspended over and around the burner by a wire support *d*. This network, or mantle, is composed of threads of incombustible material, which becomes brilliantly incandescent when

highly heated, and thus converts heat into light. The light emitted from the base of the mantle is so brilliant that it is painful to look at directly; therefore, such lamps, if intended for office or domestic use, should be provided with a shade *c* of white or opal glass, to modify the intense glare.

232. The **mantle** is made by saturating a delicate woven cotton fabric into a dense solution of several earthy oxides, such as magnesia, zirconia, etc. The mantle is then baked, and finally its temperature is raised high enough to destroy the cotton fibers, leaving the coating of oxides standing as a network of fragile crust. The fragility of the mantles is at the present time the chief drawback to this mode of gas lighting.

This lamp is not limited to the use of illuminating gas. Any variety of combustible gas, oil vapor, or gasoline may be used, by providing a suitable burner which is capable of heating the mantle to the proper degree.

BURNERS FOR PRODUCING HEAT.

233. All burners which are designed to produce *heat* rather than light, are constructed to mingle the gas with more or less air before burning. They, therefore, belong to the class known as **atmospheric** burners. There are two varieties of these burners now in common use—the *Bunsen* and the *Fletcher* burner.

234. The **Bunsen** burner, shown in Fig. 88, is named after its inventor.

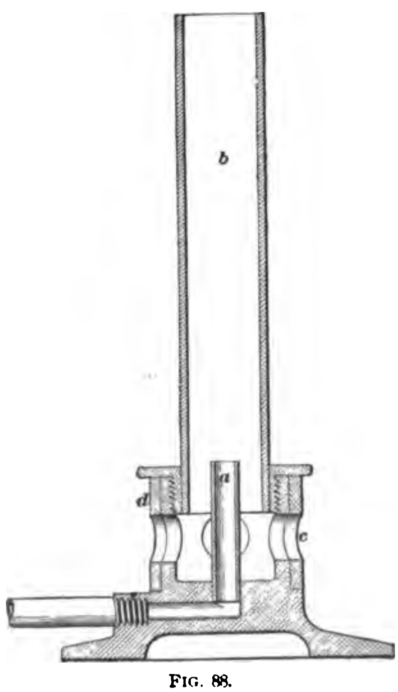


Fig. 88.

It consists of a gas tube *a* which projects part way into a large tube *b*, called the mixing tube. Air is admitted through holes *c*, which are closed or regulated by means of the collar or slide *d*. The gas issuing from *a* and the streams of air from the holes *c* mingle in the upper part of the tube *b* and form a mixture which will burn over the mouth of the tube. The flame will be quite large and unsteady, and if illuminating gas be burned, it will show a pale blue color with a tendency to green. If the proportion of air is sufficient to make the mixture combustible without the aid of the atmosphere, the flame will flash back with a sharp puff or explosion, and will then burn at the orifice of *a* with an ordinary yellow smoky flame. To prevent this, the slide *d* must be adjusted so as to restrict the supply of air just below the *explosion limit*. If the air supply is much too large, the explosion may be sufficiently violent to extinguish the flame.

235. In the **Fletcher,** or **solid flame,** burner, the top of the chamber is covered with stout wire gauze, and the gas burns as it issues through the meshes of the gauze. By this arrangement, the gas is provided with nearly or quite all of the oxygen that it requires for combustion, and, consequently, burns close to the gauze with a small compact flame of great intensity. The color of the flame, when using ordinary illuminating gas, is a bright green with a few traces of blue. The Fletcher burner is able to develop a higher heat from the gas than the Bunsen burner, because it permits a larger proportion of air to be mixed with the gas, the flame being prevented from blowing back by the wire gauze.

236. The variety of burner commonly employed in cooking stoves is constructed on the Bunsen-burner principle. Cooking-stove burners are frequently made with two or more rings of jets. Each ring should have its own mixing tube and gas-cock, so that one or all of them may be used as desired.

The best service can be had from an atmospheric burner

by regulating both the air and gas supply at the same time. For this purpose *compound cocks* are now made which control both inlets simultaneously.

Gas stoves, gas grates, gas logs, and water heaters are all heated by means of atmospheric burners.

237. A **gas log** is shown in Fig. 89. The log is made of fireclay, and is perforated with a large number of small

FIG. 89.

orifices, through which the mingled gas and air, or the gas only, passes out and burns. The log is hollow, and its interior serves as a chamber in which the gas and air are mixed before combustion. The heat is radiated directly from the small flames which nearly cover the surface of the log. The valve which controls the gas supply is located under the floor, the handle being a little above the floor, as shown.

FIXTURES.

238. The term **fixture** is applied to the apparatus which supports the gas burners and serves to connect them to the supply pipes. They are divided into three general classes: **brackets,** or **side lights,** which project from the walls; **pendants,** or **chandeliers,** which hang from the ceiling; and **pillar lights,** which stand upon a base, such as a mantel, a table, or a newel post.

Brackets made without joints are called *stiff* brackets, and those having flexible joints are called *swing* brackets.

All fixtures which hang from the ceiling may properly be called pendants; but, as commonly applied, this name is restricted to fixtures carrying one or two lights, and which are of plain construction. If the number of lights is greater, or the construction is decidedly ornamental, the term *chandelier* is used instead.

239. There is another class of fixtures called *sun lights* and constructed in a great variety of ways. They are used chiefly to produce a great amount of light near the top or ceiling of large audience rooms, and also to furnish copious illumination for show windows, etc.

A **sun light** consists of a large group of small gas burners, which are attached directly to the supply pipe, and a reflector, which is adapted to throw the light downwards as much as possible. The group is made up in a circle, or sometimes in a rectangle or in parallel lines. The burners are usually set so closely together that when one is lighted it will ignite the adjoining jets, and thus light up the whole group. The flames, however, should not touch each other when burning.

240. Common ornamental fixtures are usually built over a frame, or skeleton, of plain brass or iron tubing. The ornamental part consists of thin tubes, or shells, of brass, which are slipped over the main tubing, and are bound in place by screwing the various fittings tightly together. The

best grade of fixtures, however, are made of solid brass or bronze.

241. An **extension,** or **telescopic,** chandelier is shown in Fig. 90. The fixture is provided with two tubes, an inner

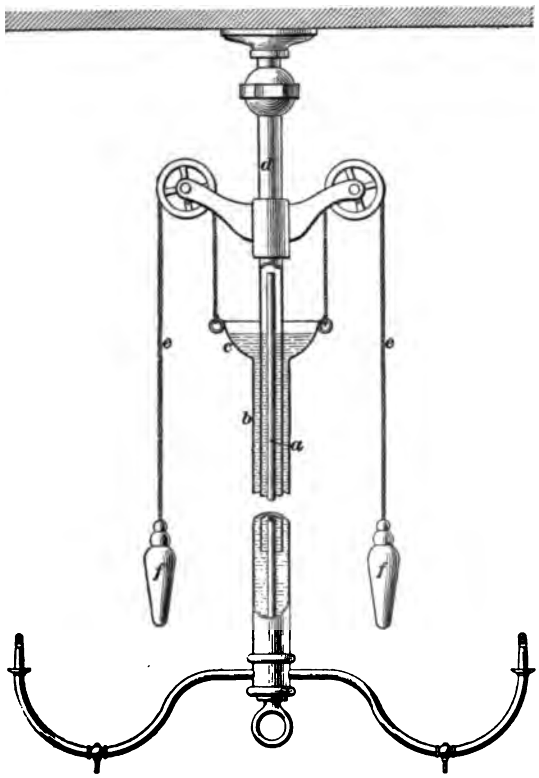


FIG. 90.

one *a*, which serves to conduct gas to the burners, and an outer one *b*, which has a cup *c* at the top end. The space between the tubes *a* and *b* is filled with liquid, and the supply pipe *d* dips below its surface at all times, thus preventing the gas from escaping. The pendant is held up by chains *e* and weights *f*, and it can be raised or lowered as desired. The chains are provided with stops to prevent the pendant

from being lowered so far that the liquid may uncover the end of the pipe *d*. Instead of the chains and weights, coiled springs (like sash balances) are frequently used to sustain the fixture. The liquid may be either oil, glycerine, or mercury; water is unsuitable because it evaporates rapidly.

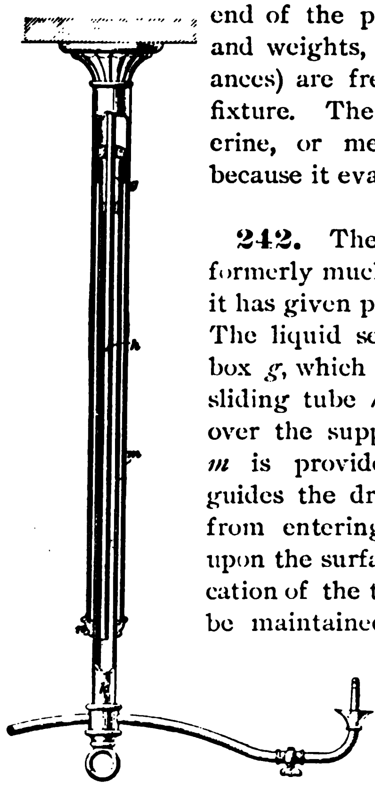


FIG. 91.

242. The chandelier just described was formerly much in use, but in recent years it has given place to that shown in Fig. 91. The liquid seal is replaced by a stuffing-box *g*, which is attached to the top of the sliding tube *k*, and which slides gas-tight over the supply tube *h*. The outer tube *m* is provided with a collar *n*, which guides the draw tube *k* and prevents dust from entering the interior and settling upon the surface of the tube *h*. The lubrication of the tube and stuffingbox can thus be maintained for a long time. As the tube *h* has only to supply gas, it can be made quite small in diameter. The devices used for balancing or sustaining this fixture in position are of many kinds. One of the best of these is a friction clutch which permits the draw tube to slide upwards without resistance, but which grips it and prevents it from moving downwards, except when pulled down by force.

DETAILS OF FIXTURES.

243. Igniters are devices for lighting gas burners, either singly or in groups, and are designed to save the time and labor which would be required to light them by hand.

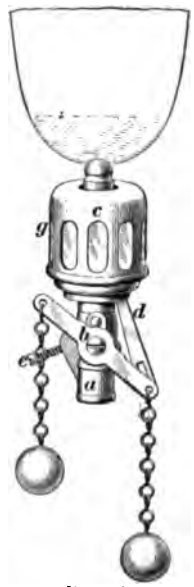


FIG. 92.

A **self-lighting** gas burner is shown in Fig. 92. The key is so made that the gas can never be entirely shut off, and when it is turned to extinguish the light, a small amount of gas is still allowed to pass, enough to maintain a small **peep** of flame at the tip of the burner. In order to protect this little flame from extinction by drafts of air, it is enclosed by a cap or globe *g*. When the burner is in full operation, the globe drops down below the flame to the position shown; but when the lever *b* is reversed to shut off the gas, the link *d* operates to raise the globe above the top of the burner, thus shielding the little flame from accidental extinction. The lower end *a* is a socket, threaded and soldered to fit the ordinary fixture. The fixture to which this burner is attached must be provided with a key, as usual, so that the burner may be entirely extinguished when desired.

244. Sun lights, and other large groups or clusters of burners, are usually lighted in a similar manner. When the cluster is extinguished, one small tip is left burning, and this serves to relight the whole group when the gas is again turned on. This small burner is commonly called a **pilot light,** and it is supplied with gas by a separate pipe. The supply of gas to all the other burners is controlled by a single cock, so that they may be turned down simultaneously, and may be extinguished or promptly relighted whenever desired.

There are also a large number of igniting devices which operate by means of electricity. Two methods are in use: in one an electric spark is caused to flash through the stream of gas issuing from each burner, thus igniting it; in the other, a small piece of platinum wire is heated to incandescence near the tip of each burner, the electric current

being turned on after the gas issues from the burners, and shut off as soon as the lights appear.

245. Safety burners are designed to close a valve and shut off the gas when the flame is extinguished. A great many devices of this kind have been patented, but few, if any, will operate with a sufficient certainty to be worthy of confidence. Nearly all of them employ bars of metal or other substances which are expanded by the heat of the flame, and while in that condition hold the gas valve open. When the flame goes out, the expanding body contracts by cooling and permits the valve to close.

The great need for safety burners arises from the fact that when the gas supply is interrupted or shut off, every burner is extinguished, but the keys are not closed. When the gas comes on again, it streams out of each open burner, and in many instances does great damage by causing explosions or by suffocating the inmates of the building.

246. Globes.—The primary object of enclosing a gas burner within a globe is to protect the flame from interference by drafts of air. A globe, however, acts as a chimney and causes a strong upward current of air to flow through it. If the dimensions of the globe are not suited to the size of the flame, the air-current will cause the flame to flicker badly, and the globe then becomes a detriment instead of an advantage.

The opening at the top or bottom of a globe should never be less than 4 inches in diameter for an ordinary 5-foot burner, and a larger size is still better.

Globes are often required to serve the purposes of shades, to modify and soften the light. For this purpose the outer surface of the glass is etched, or **ground**, or colored glass is employed. These globes obstruct the light, the loss being about as follows:

Ground glass globes............	10 to 30 per cent.
Opal glass globes	30 to 40 per cent.
Colored glass globes............	40 to 60 per cent.

Globes of clear glass obstruct the light somewhat; but, if a globe is properly proportioned, the intensity of the light will be increased by the draft which it creates, and the increase of light will counterbalance the loss by obstruction.

247. Shades are commonly used to obstruct the light from passing upwards, and to reflect a considerable part of it downwards. It is, therefore, desirable that the under side of the shade should have a good reflecting surface. For table and desk lights, the shades should be made of opaque material, and should act as reflectors only.

The color of globes and shades is a matter of some importance. If translucent shades are used, they should be either white or opal. Red, green, and blue shades should not be used, because of the bad effect of the colored light upon the eyes, red light, especially, being very tiresome to sensitive persons.

The central opening in the top of the ordinary shades permits a considerable portion of the light to pass upwards to the ceiling. When it is desired to prevent this, top reflectors may be used to intercept the light and throw it downwards, as shown at *a* in Fig. 93.

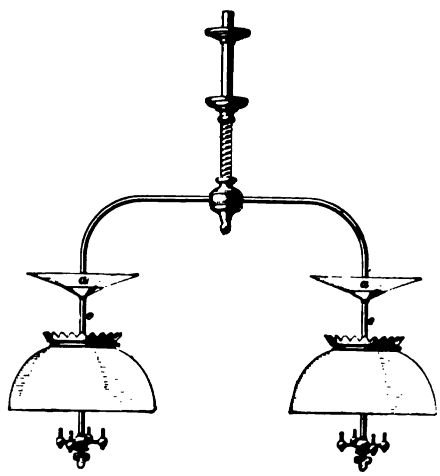


FIG. 93.

248. Shields.—The distance between an ordinary gas burner and the ceiling should be not less than three feet. If a less distance is unavoidable, the ceiling should be protected by a metal shield to prevent it from being scorched or burned. The shield should be separated from the ceiling by a clear space of at least two inches, to permit air to circulate between them. Even when a shield is provided, a gas flame should

not be permitted at a distance less than eighteen inches below the ceiling.

If a gas flame is liable to come into accidental contact with inflammable materials, such as curtains or drapery blown by the wind, or hay and straw in stables, etc., it should be provided with a glass globe, and should also be enclosed within a stout wire cage at least ten inches in diameter. The only safe way to determine the proper size of the wire guard is to test it by holding pieces of cloth or paper against it. If the material can be set on fire, the guard should be made larger.

249. The **discoloration of ceilings** may be mitigated, although not wholly cured, by using a deflector, as at *a* in Fig. 93, or by hanging an ordinary smoke-bell over the flame. By spreading out the current, its velocity is checked, the amount of dust which strikes the ceiling within a given area is thus reduced and the discoloration is lessened.

The only *effectual* method of preventing the discoloration of walls and ceilings in this manner is to intercept the current of hot air arising from each burner, and to conduct it to a chimney or ventilating flue, by means of a hood suspended over each flame, or set of flames, and suitable pipe connections. This plan is valuable for another reason. Not only are the products of combustion removed from the room, but a considerable amount of air is carried along also, thus aiding ventilation. The hot gas which is discharged into the ventilating flue raises the temperature therein, and thus increases the draft and improves the operation of the flue.

LOCATION OF GAS FIXTURES.

250. The chief considerations which govern the location of gas fixtures are: first, that they shall light the rooms to good advantage; and, second, that they shall cause no danger from fire.

In lighting *bedrooms* the fixtures should be located so that the bed, wardrobe, dressing case, mirror, etc. may be placed in desirable positions without interfering with the light.

The positions of the closets should be noted, and, if practicable, the light should be arranged to shine into them, so that the contents may be easily seen.

Dressing mirrors should be provided with two stiff-bracket lights, one at each side. They should be placed as high as they can conveniently be reached, in order to properly illuminate the head and shoulders of the person using the mirror.

In *bathrooms* the lights should be set high, so that a person will not be liable to strike them in taking off or putting on clothing. A light should not be located *over* a bath tub or a wash bowl, or anywhere near them, because of the liability to accident.

Stairways should be provided with a light at the top, whether there is one at the bottom or not. A light on the newel post alone is not sufficient to properly illuminate the steps. People having defective sight are especially liable to accident on stairways, and the light should be arranged so as to avoid all shadows which might prove deceptive.

A *kitchen* or *laundry* should be lighted by pendants whenever practicable. If side lights must be used, they should not be placed over the sink or near enough to it to be liable to be struck, or be splashed with water. The best place for a side light is usually over the pastry table.

A side light should not be placed over a set of tubs if it can be avoided. A better place is at the head of the ironing table.

The stairway leading from the kitchen to the basement, or cellar, should be lighted by a burner which is located some distance away from the foot of the stairs. If the light is near the foot of the stairs, it is very likely to be struck when large articles are carried past it.

Hallways are best lighted by a pendant; if a side light is used, it should be placed where it will not interfere with the coat rack, or mirror, or other hall furniture.

A pendant in a hallway or vestibule should be set so high that the globes will not be liable to be knocked off by a person who is putting on an overcoat, etc.

Chandeliers should be hung from the center of the ceiling as nearly as practicable. If several side lights are used in the same room, they should be placed at the same height.

Swing brackets should not be used for lighting hallways, stairs, vestibules, or other passageways, because of the danger from fire. The light is very liable to be swung too close to the wall, and to be overlooked until the building is set on fire. Swing brackets are always a source of danger when they are located within reach of woodwork or drapery, and, therefore, are not to be recommended for general use. It is preferable, in most cases, to use instead, two single lights on stiff brackets, or else a bracket having two or more rigid arms with fixed lights.

A gas fixture should never be placed in a *closet* or other very small room, if there is any chance that the door may be closed and the light left burning. If that should happen, the temperature would rise rapidly, and there would be great danger of setting fire to any combustible material that might be in the room.

Care should be taken in locating side lights, to make sure that wooden doors cannot be swung back against them, and be scorched or set on fire. Lights should not be placed where they may be blown out by strong drafts of air, or by the sudden slamming of a door. A gas burner when extinguished, with a full head of gas on, is very dangerous.

Hot-air registers in the floor or wall should be carefully avoided in locating gas fixtures. If a light is over or near a register, it will flicker incessantly, and will be a great annoyance.

251. The proper **height** of gas lights above the floor depends somewhat upon circumstances. In ordinary dwellings having a ceiling 9 feet high or more, side lights should be placed from $5\frac{1}{2}$ to 6 feet high. Pendants may be hung from $6\frac{1}{2}$ to 7 feet from the floor. If the rooms are large and high, the lights of chandeliers may be placed at a height of 7 to 8 feet, or even more. Of course, all lights above 7 feet high will require the assistance of a torch or step ladder to light them.

Side lights in hallways and vestibules of churches, and similar buildings, should be placed at a height of at least 7 feet.

Low lights should be avoided, because they are tiresome to the eyes. If they must be used, they should be provided with opaque shades, as before mentioned.

ILLUMINATION.

252. The ideal of artificial illumination is to have the light coming from overhead, and to have it so thoroughly diffused that no object in the room shall appear conspicuously brighter than any other.

While it is impracticable to attain this ideal, with the means at hand at the present time, yet it should be so kept always in mind that mistakes in lighting may be avoided.

Lights of great brilliancy, such as electric arc lights, not only dazzle the eye, but frequently produce blindness. Oculists strongly condemn them, because they impair the vision of persons using them. The trouble is due mainly to the brilliancy of the light.

In using artificial lights for illumination, the aim should be to illumine all objects within the ordinary field of vision to about the same degree of brilliancy as that afforded by *diffused* daylight. Objects which are lit up by direct sunlight are usually too bright to look at continuously.

The flames of gas burners or lamps are much too bright to be looked at directly, therefore they should be screened so that whatever light reaches the eye shall be reduced to a moderate intensity.

The physiological effect of a light which shines in the eyes of a person who is looking at something else, is to produce considerable nervous irritation and fatigue, if long continued. Thus, if a gas burner or kerosene lamp, or any bright object, comes within the ordinary field of vision while a person is listening to an address, and is looking towards the speaker, it will cause a great deal of uneasiness. A few

lights misplaced in that way will fatigue an audience to a greater degree than is generally supposed. Therefore, all lights which are located in the vicinity of a person addressing an audience, either above or behind, or at either side, should be fully covered by opaque screens which will prevent any light from passing towards the audience.

While the irritating brilliancy of such lights may be mitigated by means of globes of white or opal glass, yet they continue to be conspicuously bright, and are very objectionable. The best result is obtained by using opaque screens which reflect the light back upon the platform.

For similar reasons all chandeliers or pendants should be hung so high that the lights will not come within the field of vision of any person looking towards the platform or speaker.

253. Large audience rooms, such as churches and lecture rooms, can be illuminated to best advantage by means of groups of small burners which are located near the ceiling, and are provided with proper reflectors to project the light downwards. These sun lights may be arranged in a great many ways, and can be adapted for almost any kind of service. The light which they give is more agreeable than that from a single burner of equal power, because it proceeds from a large number of flames, and is thus so diffused that the shadows are very *soft* or indistinct.

This method of lighting is correct in principle, and it should be employed for domestic lighting to a much greater extent than it is at present. While there are some difficulties in carrying out the plan on a small scale, yet these should act as a stimulus to invention rather than as a bar to improvement. The introduction of the modern high-power lamps, such as the Wenham regenerative and the Welsbach incandescent, makes it very necessary that great improvements be made in the modes of distributing and diffusing light. There is a great need of such improvements in domestic illumination.

Flat gas flames, when turned horizontally, give a brighter

illumination to objects below them than when burning in the ordinary erect position. The gas flames in overhead sun lights should always be horizontal.

AMOUNT OF LIGHT REQUIRED.

254. Rooms having dark-colored walls, or having much colored drapery, will require more light than they would if finished in white. The white walls reflect and disperse the light, thus aiding the general illumination, while colored walls reflect less in proportion to the brightness of their coloring.

The rule commonly used for computing the number of ordinary 5-foot Batswing burners which will be required to properly illuminate a church or other large room is as follows:

Rule.—*Divide the area of the floor of the room by 40; the quotient will be the number of burners required.*

If there are balconies, etc. extra lights must be provided for them by the same rule. The divisor given may be varied from 40 to 80 to suit smaller rooms, such as are found in ordinary dwellings. The reflection from the walls is proportionally greater in small rooms; therefore, a less number of burners is required in proportion to the actual floor space.

EXAMPLE.—How many 5-foot Batswing burners will be required to properly illuminate a church having an auditorium 70 ft. $\times$ 100 ft., and a balcony having 2,000 square feet floor area?

SOLUTION.—The main floor will require $\frac{70 \times 100}{40} = 175$ burners, and the balcony will require $\frac{2,000}{40} = 50$ burners; $175 + 50 = 225$ burners. Ans.

One 5-foot burner is assumed to give a light of 16 candlepower. The amount of light required is, therefore, 16 candlepower to a floor space of 40 square feet in large rooms, to 80 in small ones, or .4 to .2 candlepower per square foot of floor space.

PHOTOMETRY.

255. The capacity of the human eye for the perception of light is comparatively small. It is unable to perceive very faint lights, and it is dazzled and confused by lights of great brilliancy. Photographic plates are affected by faint lights which are invisible to the eye; thus, photographs of the sky reveal a multitude of stars which are not visible even with the aid of the strongest telescopes. The unaided eye is unable to judge of the relative intensity of various lights with any reasonable approach to accuracy.

256. The art of measuring the comparative intensity of lights is called **photometry**. There are several methods of making these measurements—chemical, electrical, and mechanical—each of which is peculiarly suited to special cases. The method employed for general purposes is to compare the illuminating power of the light under examination with that of a light of standard intensity.

The unit which is used for all ordinary measurements is the light given by a sperm candle, which burns at the rate of 120 grains per hour.

The candle is burned in still air, and care is taken to avoid all drafts which might accelerate the combustion, and thus vary the brilliancy of the light. The light thus obtained is made the unit for comparison, and is called one **candlepower.**

A larger unit is sometimes used for measuring very large lights. This is the flame of a certain variety of oil lamp called the Carcel lamp, and the unit thus derived is called one **Carcel.**

257. All instruments which serve to measure the comparative brilliancy of lights are properly called **photometers.**

One of the oldest of these instruments, called the **Rumford** photometer, is shown in Fig. 94. It consists of a table having a black wooden post *c*, standing erect as shown, and a screen *g*, which receives the shadows of the post that are

cast by the lights *a* and *b*. The candle *a* is the standard light, and *b* is the light whose intensity is to be measured. The lines *h c* and *i c* make exactly equal angles with the screen, and the lights are moved back and forth along these

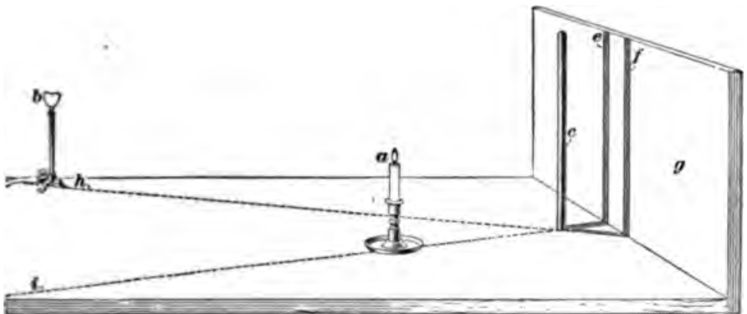


FIG. 94.

lines until the shadows *e* and *f* appear of exactly equal blackness. The powers of the two lights are then computed by dividing the square of the distance *b c* by the square of the distance *a c*, the quotient being the candlepower of the light *b*.

This method is very inaccurate, and is not to be recommended, because the eye is unable to compare the shadows *e* and *f* with the requisite accuracy.

258. The **Bunsen** photometer, shown in Fig. 95, operates upon a different principle. A diaphragm *c* is illuminated on its opposite sides by the light *b* and the standard

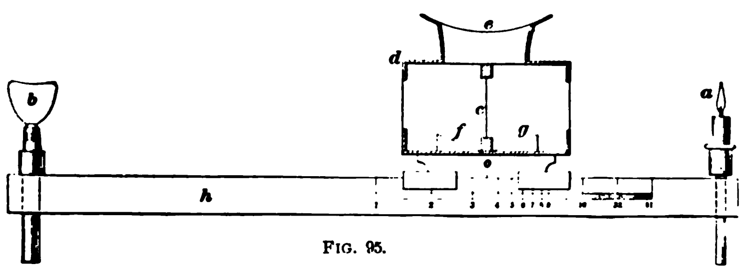


FIG. 95.

candle *a*. The observer looks down through the tube *e* into mirrors *f* and *g*, and thus sees the reflection of both sides of

the diaphragm at the same time. If they appear of unequal brilliancy, the *sight-box d* is moved along the bar *h* until they become equal. The candlepower of the light *b* is then found by dividing the square of the distance *b c* by the square of the distance *a c*; usually the bar is graduated, as shown, so that no calculation is necessary.

259. There are two methods of constructing the diaphragm in vogue. The **spot** diaphragm is shown in Fig. 96. The center *a* is a disk of opaque white paper. The ring *b* is made of white paper which is saturated with paraffin, and is translucent. The outer part *c* is blackened. When this diaphragm is unequally illuminated on its opposite sides, the ring *b* looks darker, or brighter, than the center *a*, but when the illumination is exactly equal, all difference disappears, and the spot *a* becomes indistinguishable.

FIG. 96.

The **star** diaphragm is shown in elevation at *A*, and in section at *B* in Fig. 97. It consists of a piece of white writing paper *a* of moderate thickness, having a star-shaped figure cut out of its center, and a sheet of thin white writing paper *c* of best quality, which is doubled so as to enclose the piece *a*. The diaphragm is lightly squeezed between two pieces of glass *b*, *b*. Care is taken in cutting the star to make every point and line clear and sharp. When the reflection of the diaphragm is seen in the mirrors, the images will vary in *distinctness* if the lights are unequal. The sight-box *d* in Fig. 95 is then moved along the bar until both images of the star appear equally sharp and clear.

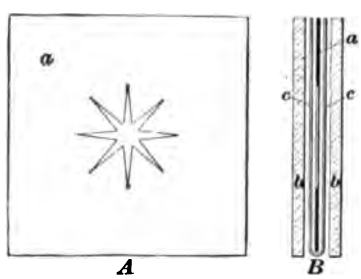


FIG. 97.

It will be observed that the methods of testing employed

in the photometers described are quite different. In the Rumford method the observer judges the equality in blackness of the shadows produced; in the Bunsen method, using the *spot* diaphragm, he judges by the equal brightness of the opposite sides of the diaphragm, and when using the *star* diaphragm, he judges by the equal clearness and distinctness of the two images of the star.

The Rumford method has been discarded for the more accurate Bunsen method. Both the spot and star diaphragms are widely used; but the star diaphragm is preferred because of its superior accuracy.

260. In practice the distance between the centers of the lights, Fig. 95, is usually made 100 inches, and the bar is graduated according to the following table, the numbers given being the distance in inches from the center of the candle flame to the center of the diaphragm for each candlepower.

TABLE 11.

1	50.00	11	23.17	21	17.91	31	15.22
2	41.42	12	22.40	22	17.57	32	15.02
3	36.61	13	21.71	23	17.25	33	14.83
4	33.33	14	21.09	24	16.95	34	14.64
5	30.90	15	20.52	25	16.67	35	14.45
6	28.98	16	20.00	26	16.40	36	14.28
7	27.43	17	19.52	27	16.14	37	14.12
8	26.12	18	19.07	28	15.90	38	13.96
9	25.00	19	18.66	29	15.66	39	13.80
10	24.04	20	18.27	30	15.43	40	13.65

The distance x (equal to ac in Fig. 95) for any candlepower (c. p.) for any distance L between centers of the lights, may be computed by dividing L by 1 plus the square root of the candlepower; thus, $x = \frac{L}{1+\sqrt{c.\ p.}}$.

261. In using the photometer, care must be taken to prevent the entrance of light into the sight-box from any

other source than the lights which are to be compared. A screen of black velvet should be suspended behind each light to prevent any light from being reflected towards the sight-box.

It is not necessary to have a darkened room to operate in if the instrument is properly protected with curtains and screens of black cloth.

In testing gas, the pressure must be kept uniform, and the rate of combustion should be carefully measured. Standard candles can be obtained from the American Meter Co., New York.

The candlepower of ordinary illuminating gas is measured while burning at the rate of 5 cubic feet per hour, under a pressure of .5 inch of water. To secure very exact measurements, small corrections must be made for the temperature of the gas and for the moisture contained in it.

The candle should always be weighed before and after each test, and allowances must be made in computing the candlepower of the light under examination, if the rate of consumption of the candle varies either way from the standard rate of 120 grains per hour.

HEATING AND VENTILATION OF BUILDINGS.

HEAT.

THE NATURE OF HEAT: TEMPERATURE.

1. Composition of Matter.—Matter—that is, the substance of which bodies are composed—is made up of **molecules.** A molecule is defined as the smallest portion of matter that can exist in an independent state. Every body is composed of millions of these molecules, held together by a force called **cohesion.** It is supposed that these molecules are separated by spaces, and that they are continually in a state of motion, vibrating back and forth, with a greater or less velocity, and continually approaching and receding from one another.

2. Heat a Form of Energy.—The motion of the molecules composing matter gives rise to the phenomenon of heat, and causes the sensation of warmth or cold. When the motion is slow, the body feels cold to the touch; if, on the other hand, the vibrations are rapid, the body is warm or hot. Heat is therefore not a *substance*, but a manifestation of *motion*, or, as it is usually expressed, *heat is a form of energy.*

3. Temperature.—Temperature is a term used to indicate how hot or cold a body is—i. e., to indicate the rate of

vibration of the molecules of a body. A hot body has a high temperature; a cold body, a low temperature. When a body, as, for example, an iron bar, receives heat from any source, its temperature rises; on the other hand, when a body loses heat, its temperature falls.

The temperature is *not* a measure of the quantity of heat a body possesses. *Temperature* may be considered to be a measure of the velocity of the molecules of a body as they vibrate to and fro, while the *quantity of heat* may be considered to be the kinetic energy of the molecules composing the body. A small iron rod. may be heated to whiteness and yet possess a very small quantity of heat. Its temperature is very high, which simply indicates that the molecules of the rod are vibrating with an extremely high velocity.

Temperature is measured by an instrument called a *thermometer*, which is so familiar as to scarcely need description. It consists of a thin glass tube, at one end of which is a bulb filled with mercury. Upon being heated, the mercury expands in proportion to its temperature. Thermometers are graduated in different ways. In the Fahrenheit thermometer, which is generally used in this country, the point where the mercury stands when the instrument is placed in melting ice is 32°. The point indicated by the mercury when the thermometer is placed in water boiling in open air at the level of the sea is marked 212°. The tube between these two points is divided into 180 equal parts, called degrees.

4. Latent Heat.—Suppose we take a block of ice at a temperature of, say, 14° and heat it. If a thermometer is placed in contact with the ice, its temperature will rise until it reaches 32°, and will then remain stationary. As soon as this temperature is reached, the ice begins to melt, or change to water, and the heat, instead of raising the temperature further, is all used to effect this change of state. In a similar manner, if sufficient heat be applied to a quantity of water, it will eventually change it to steam. One of the effects of heat, therefore, is the changing of a solid to a

liquid, or of a liquid to a gas. The heat which is thus expended in changing a body from the solid to the liquid state, or from the liquid to the gaseous state, is called *latent heat*. The portion of the heat applied which raises temperature, and which, therefore, affects the thermometer, is sometimes called *sensible heat*.

5. Measurement of Heat.—Since heat is not a substance, it cannot be measured directly in pounds or quarts; but, like force, it may be measured by the effects it produces. Suppose a certain quantity of heat raises the temperature of a pound of water from 52° to 53°. It will take the same quantity of heat to raise the pound from 53° to 54°, and it will take double the quantity to raise the temperature of the pound of water from 52° to 54° that it took to raise the temperature from 52° to 53°. The unit quantity of heat is the quantity required to raise the temperature of a pound of water from 62° to 63°. This unit is called the **British thermal unit**, or B. T. U.

HEAT PROPAGATION.

6. Heat may be transmitted by *radiation*, by *conduction*, and by *convection*.

7. Radiation.—The tendency of heat is to pass away from a warm body instantaneously, and with equal energy in all directions. This manner of transit is called **radiation.** Strictly speaking, all heat is *radiant heat*, because it invariably proceeds by radiation when it is not obstructed or retarded by the medium or material through which it passes. All known materials retard the transmission of heat to a greater or less degree. Thus, dry air permits heat to pass through it with very little obstruction, but wood offers great resistance.

If a person attempts to warm himself at a blazing fire, out of doors, on a cold day, he may be scorched on one side by the radiant heat of the fire at the same time that he is

almost frozen on the other side by the cold air which surrounds him. The air which is between him and the fire thus permits the heat to pass through it without raising its temperature to any considerable degree.

8. Intensity.—The law which governs the *intensity* of radiant heat is as follows:

The temperature is inversely proportional to the square of the distance from the source of heat.

Thus, the heat which is received upon a surface 1 foot square at a distance of 5 feet will diverge and cover a space of twice that width and height, having four times the area at a distance of 10 feet; the heat, being spread over four times as much surface, can have only one-fourth the intensity.

9. Reflection.—Heat may be reflected, dispersed, or concentrated by means of mirrors or lenses, in the same manner as light. The following table shows the reflecting power of various substances, when the heat rays fall upon them at an angle of 90°, in percentage of the total radiant heat received:

TABLE 1.

REFLECTING POWER.

	Per Cent.		Per Cent.
Polished silver	97	Polished zinc	81
Polished brass	93	Polished iron	77
Polished copper	93	Bright tin	85
Polished steel	83	Glass	10

Thus, polished silver will reflect 97 per cent. and will absorb 3 per cent. of the radiant heat falling upon it. The metal will slowly become warmed by the heat absorbed.

10. Conduction.—When the transmission of heat through any certain substance requires a measurable amount of time, the manner of transmission is called **conduction.** Thus, it becomes clear that the distinction between radiation and conduction has regard to the *rapidity*

of the transmission, radiation being *instantaneous* transmission, and conduction being merely *retarded* transmission. All known substances will conduct heat to a measurable extent, but the rapidity of the conduction varies greatly in different materials. Thus, substances are classed as **good conductors,** or **bad conductors,** according to the rapidity with which they will conduct heat.

All metals will conduct heat internally much faster than they can either absorb it at, or emit it from, their surfaces. It will be seen, therefore, that a knowledge of their actual *conducting* power is not so valuable or essential in the arts of heating and ventilation, as a knowledge of their *transmitting* power.

11. The law which governs the distribution of heat by conduction is as follows:

All bodies within a given enclosure tend to come to an equal temperature; and the heat within any certain body will tend to diffuse uniformly throughout its whole extent.

If one or more of the bodies have a higher temperature than the others, an interchange of heat will take place, until all are equally heated.

12. The following table shows the relative conducting powers of various materials, silver being taken as the standard:

TABLE 2.

Silver	100	Cast iron	17.0
Copper	77	Zinc	20.0
Brass	33	Tin	15.0
Steel	12	Lead	8.5

When heat passes from a dense substance to one less dense, or the reverse, the transmission is considerably retarded, and the condition of the surface through which it passes determines the rapidity of the passage.

13. The **absorptive** and **emissive** powers of various substances are shown in the following table:

TABLE 3.

Lampblack, dry	100	Steel	17
White lead, dry powder	100	Polished brass	7
Paper	98	Polished copper	7
Glass	90	Polished silver	3

Color does not affect the heat-absorbing capacity of the material.

14. Convection.—If there is any difference in the condition of the various layers of a body in weight, electric tension, or chemical condition, they will move about until all the particles have acquired the same condition. The minute motion of each particle is called *convection*, and the general movement of the mass upon itself is called *circulation*.

EXPANSION.

15. If a body absorbs heat, its volume will be changed correspondingly. Nearly all bodies expand when heated; a few substances are known which contract, but these exceptions are of no practical importance.

Air and all other gases expand *uniformly* for each degree of rise in temperature above zero. Air, at zero F., will expand $\frac{1}{460}$ of its volume for each degree of rise in temperature. Thus, air at 70° will have a volume equal to $1 + \frac{70}{460}$, or $\frac{530}{460}$ of its volume at zero, if its tension remains unchanged. By *tension* is meant the pressure which a gas exerts on the vessel which confines it.

The volume of water does not increase at the same rate as the temperature; therefore, the increased volume due to a rise of temperature can only be determined by experiment.

Water is practically incompressible, and it expands with as much force as ordinary metals. When water is heated or

cooled, the vessel or pipes which contain it expand or contract also, but to a less degree.

The expansion of wood by heat is so small that it may be neglected.

16. A consideration of the nature of heat readily explains the phenomenon of expansion. When a body, as, for example, a bar of iron, is heated, its molecules begin to move more rapidly and in longer paths. The more the body is heated and the higher its temperature, the farther apart the molecules are driven, and consequently the greater the volume of the body.

The *linear expansion*, or extension, of metals for one degree rise of temperature is given in the following table:

TABLE 4.

Material.	Increase of Length in 1 Foot for an Increase in Temperature of 1° F. Inches.	Material.	Increase of Length in 1 Foot for an Increase in Temperature of 1° F. Inches.
Cast iron.....	.0000740	Lead........	.0001900
Wrought iron.	.0000823	Tin.........	.0001692
Steel tubes...	.0000719	Glass........	.0000550
Brass........	.0001244	Brick........	.0000144
Copper	.0001146	Firebrick	.0000333
Zinc.........	.0001961	Marble	.0000566

17. The **amount** of the **expansion** or contraction of a bar or pipe, having a given length, which will be caused by any given change in its temperature, may be found as follows:

Rule 1.—*Multiply the length in feet by the number of degrees of change in temperature. Multiply this product by the coefficient given in the above table, for the material employed. The result will be the change of length in inches.*

EXAMPLE.—How much will a steel tube 14 feet long expand, if its temperature is raised 80°?

SOLUTION.—From Table 4, the coefficient of linear expansion per unit of length for a rise in temperature of 1° is found to be .0000719 for steel tubes. Hence, using rule **1**, the increase of length is $14 \times 80 \times .0000719 = .0805$ in. Ans.

18. If metallic bodies are heated above a certain degree (which varies for different metals), and the heat is continued for any considerable length of time, the metal will become permanently elongated, and upon cooling will not contract to its original dimensions. The metal is then said to be *swelled*. Thus, grate bars in a furnace, or pipes which are exposed to intense heat, will increase considerably in length during long use. The strength of the metal deteriorates at the same time. Thus, plates or parts of furnaces which are unduly heated will swell permanently, and bulge or crack the adjoining parts.

SPECIFIC HEAT.

19. As stated in Art. **5**, one B. T. U. will raise the temperature of a pound of water from 62° to 63°. The question arises, Will 1 B. T. U. raise a pound of any other substance, say mercury or iron, through the same range of temperature? Suppose two iron balls of the same weight are heated in boiling water. They will each have a temperature of 212°, and being of the same weight they must possess the same quantity of heat. Plunge one of the balls in a vessel containing, say, 10 pounds of water, and the other in a vessel containing 10 pounds of mercury. Suppose the weight of each ball is such that the temperature of the water is raised from 62° to 64° by the heat contained within the ball. Then it will be found that the mercury will be raised from 62° to 122°. That is, the same amount of heat that raises 10 pounds of water 2° raises 10 pounds of mercury 60°, or through a range of temperature 30 times as great. It is plain, therefore, that to raise a pound of mercury from 62° to 63° requires $\frac{1}{30}$ of the heat necessary to raise a pound of water from 62° to 63°. Hence, we say the *specific heat* of the mercury is $\frac{1}{30}$, or .0333.

The **specific heat** *of a body is the ratio between the quantity of heat required to warm that body one degree and the quantity of heat required to warm an equal weight of water one degree.*

EXAMPLE.—It is found that, to raise the temperature of 20 pounds of iron from 62° to 63°, 2.276 B. T. U. are required; what is the specific heat of iron?

SOLUTION.—To raise 20 pounds of water from 62° to 63° requires 20 B. T. U. The specific heat of the iron is, according to the above definition, the ratio between the quantities of heat required to warm the iron and the water, respectively, through 1 degree; that is, it is the ratio $2.276 : 20 = 2.276 \div 20 = .1138$. Ans.

EXAMPLE.—The specific heat of silver is .057; how many B. T. U. are required to raise 22 pounds of silver from 50° to 60°?

SOLUTION.—To raise the temperature of a pound of water 1 degree requires 1 B. T. U. Since the specific heat of silver is .057, only .057 B. T. U. is required to raise 1 pound of silver 1 degree. Hence, to raise 22 pounds of silver 10 degrees must require $.057 \times 22 \times 10 = 12.54$ B. T. U. Ans.

20. The specific heat of various substances is shown by the following table:

TABLE 5.

SOLIDS.

Copper	0.0951	Cast iron	0.1298
Gold	0.0324	Lead	0.0314
Wrought iron	0.1138	Platinum	0.0324
Steel (soft)	0.1165	Silver	0.0570
Steel (hard)	0.1175	Tin	0.0562
Zinc	0.0956	Ice	0.5040
Brass	0.0939	Sulphur	0.2026
Glass	0.1937	Charcoal	0.2410

LIQUIDS.

Water at 62°	1.0000	Lead (melted)	0.0402
Alcohol	0.7000	Sulphur (melted)	0.2340
Mercury	0.0333	Tin (melted)	0.0637
Benzine	0.4500	Sulphuric acid	0.3350
Glycerine	0.5550	Oil of turpentine	0.4260

GASES.

Air	0.23751	Carbonic oxide	0.2479
Oxygen	0.21751	Carbonic acid	0.2170
Nitrogen	0.24380	Olefiant gas	0.4040
Hydrogen	3.40900		

The table shows that the amount of heat which would be required to raise the temperature of 1 pound of water would be sufficient to heat to an equal degree about 8 pounds of cast iron, or 30 pounds of mercury, or 4 pounds of air, which is about 54 cubic feet.

21. Rule 2.—*To find the number of B. T. U. required to raise the temperature of a body a given number of degrees, multiply the specific heat of the body by its weight in pounds and by the number of degrees rise in temperature.*

Denote the number of B. T. U. required by U, the specific heat by c, the weight by W, and let t and t_1 be the temperatures before and after the heat is applied, respectively.

Then, $$U = cW(t_1 - t).$$

EXAMPLE.—How many B. T. U. are required to raise the temperature of 13 pounds of glycerine from 63° to 80°?

SOLUTION.—From Table 5, the specific heat of glycerine is .555; hence,

$U = cW(t_1 - t) = .555 \times 13 \times (80 - 63) = 122.655$ B. T. U. Ans.

22. Heat Contained in Water.—The quantity of heat which will be given off by a current of *hot water*, in cooling through any certain range of temperature, may be found by measuring the velocity of the current and computing the weight of the water which passes through the pipe per minute. The weight thus found should be multiplied by the number of degrees through which the water is to be cooled. The product is the number of heat units which will be given off per minute by the current in question.

LATENT HEAT.

23. In changing a solid body to a liquid, either by melting or by dissolving it, or in changing a liquid to vapor or gas, a large amount of heat may be applied without changing the temperature. Thus, a pound of ice at 32° will absorb 142.65 heat units in changing to water having the same temperature. Again, the pound of water thus produced may be heated to the boiling point, 212°, by the addition of 180.531 heat units. But, in order to convert the water at 212° into steam at the same temperature, 966.069 heat units must be added. Thus, a pound of steam at 212° contains $966.069 + 180.531 + 142.65 = 1,289.25$ heat units more than a pound of ice at 32°, although the difference in temperature is only 180°.

The heat which is thus absorbed in the process of melting or vaporization, is called *latent heat.*

The temperature at which a body changes from a solid to a liquid state is called the *temperature of fusion;* and the number of B. T. U. required to effect this change in a body weighing 1 pound is called the *latent heat of fusion.* The temperature at which a body changes from a liquid state to a vapor (gas) is called the *temperature of vaporization;* and the heat required to effect this change in one pound of the liquid is called the *latent heat of vaporization.*

When a vapor changes back to a liquid, it is said to *condense,* and when a liquid changes back to a solid, it is said to *freeze;* in either case, an amount of heat equal to the latent heat of vaporization or of fusion, as the case may be, must be abstracted from (given up by) the body before the change can be effected.

24. The following table shows the amounts of latent heat required for the fusion or vaporization of 1 pound of various substances, they having first been raised to the temperature at which the change takes place, and the pressure being 1 atmosphere, or 14.7 pounds per square inch:

TABLE 6.

Substance.	Temperature of Fusion.	Temperature of Vaporization.	Latent Heat of Fusion. B. T. U.	Latent Heat of Vaporization. B. T. U.
Water	32°	212°	142.65	966.069
Mercury	−37.8°	662°	5.09	157
Sulphur	228.3°	824°	13.26	
Tin	446°		25.65	
Lead	626°		9.67	
Zinc	680°	1,900°	50.63	493
Alcohol	Unknown	173°		372
Oil of turpentine	14°	313°		124
Linseed oil		600°		

The temperature of vaporization in the above table is the boiling point of the liquid under the ordinary atmospheric pressure of 14.7 pounds per square inch.

The variation of the boiling point by changes in pressure differs greatly in various liquids. The temperature of fusion, or the *melting point*, is similarly affected by changes in pressure, but the amount of the variation is unimportant for all the purposes of heating and ventilation.

EXAMPLE.—If 5 pounds of ice, having a temperature of 10° below zero, be mixed with hot water having a temperature of 200°, what weight of hot water will be required to melt the ice and bring the temperature of the mixture up to 60°?

SOLUTION.—The temperature of the ice is $10 + 32 = 42°$ below the freezing point. The amount of heat required to raise its temperature to the freezing point will be $42 \times .504$ (specific heat) $\times 5 = 105.84$ heat units. To liquefy the ice at 32° will require 5×142.65 (latent heat of fusion) $= 713.25$ heat units. Then, to change the ice into water at 32°, $105.84 + 713.25 = 819.09$ heat units must be applied to it. To bring its temperature up to 60°, there must be $(60 - 32) \times 5 = 140$ heat units added, which makes the total quantity of heat required, $819.09 + 140 = 959.09$ heat units.

The hot water is to be cooled from 200° down to 60°; therefore, each pound will give up $200 - 60 = 140$ heat units; $959.09 \div 140 = 6.85$ pounds of hot water will be required to furnish the 959.09 heat units. Ans.

THERMOMETERS.

25. For measuring ordinary temperatures, the mercurial thermometer described in Art. **3** is used. For measuring low temperatures, *alcohol* is used in the thermometer tube instead of mercury. Mercury becomes a solid at about 38° below zero, but alcohol remains fluid at −200°. As alcohol boils at 173°, these instruments must not be exposed to heat exceeding 150°.

For measuring high temperatures, the *air thermometer* may be used.

26. Recording Thermometers.—When it is desired to have a continuous record of the changes of temperature at any certain point, the object may be attained by means of instruments called *thermographs*, or recording thermometers.

In measuring atmospheric temperature, the thermometer should be exposed to unobstructed circulation, and should be protected from the direct rays of the sun and from radiation from all warm bodies in its vicinity. It must be kept strictly dry. If there is any moisture on the bulb, it will evaporate and cause the mercury to fall to a lower point than the true temperature of the air.

ABSOLUTE ZERO.

27. It has been found by experiment that all perfect gases will expand $\frac{1}{460}$ of their volume when heated from zero to 1° above. It is inferred, therefore, that the ultimate limit of contraction would be found at 460° below zero of the Fahrenheit scale, and that at this point all motion of the molecules ceases. This point is called *absolute zero*, and temperatures measured from this point are called *absolute temperatures*. The temperature which is indicated by the thermometer may be converted into **absolute temperature**

by adding it to 460°. Thus, a temperature of 85° by the thermometer corresponds to the absolute temperature of $85 + 460 = 545°$.

Hereafter, where temperatures are mentioned, t will denote the ordinary temperature indicated by the thermometer, and T, the absolute temperature; hence, on the Fahrenheit scale, $T = 460° + t$.

EXAMPLE.—What are the absolute temperatures corresponding to the ordinary temperatures 212°, 32°, and −39.2° Fahrenheit?

SOLUTION.— $T = 460° + 212° = 672°$. Ans.
$T = 460° + 32° = 492°$. Ans.
$T = 460° - 39.2° = 420.8°$. Ans.

EXAMPLE.—If the absolute temperature is 682°, what is the temperature as shown by a Fahrenheit thermometer?

SOLUTION.— $t = T - 460° = 682° - 460° = 222°$. Ans.

AIR AND GASES.

COMPOSITION OF THE ATMOSPHERE.

28. The atmosphere is composed of several bodies of gas, which exist independently of one another. They are thoroughly mingled by diffusion, but they are not united or combined in any way. The principal gases in the atmosphere are oxygen, nitrogen, water vapor or steam, and carbonic acid, the last in very small proportion.

The weight and density of the oxygen and nitrogen are nearly equal; consequently, it is not practicable to separate them by mechanical means. Wherever the oxygen is permitted to go, the nitrogen will certainly accompany it, because no means are known by which it may be held back.

The chemical properties of these gases are very different. Oxygen supports combustion, and is required by all living things to sustain life. In breathing air, nitrogen is taken into the lungs along with the oxygen, because it cannot be avoided. It is not known to be of any use to animals, but it is absorbed from the air and converted into useful substances by several varieties of plants, such as peas and beans,

and notably by the common red clover. Nitrogen operates to retard combustion, mainly by absorbing heat. Pure oxygen may be breathed with impunity, and persons may live in it for a short time without serious harm. But as the vital energy is so much greater than that to which the lungs are accustomed, a person breathing it would become feverish and intoxicated.

In the ordinary atmosphere the proportions of oxygen and nitrogen vary slightly at times, but not to any important extent. The average composition of 1 pound of dry air is as follows:

Oxygen..................	0.2309 lb.
Nitrogen..................	0.7687 lb.
Carbonic acid.............	0.0004 lb.

HEAT CONTAINED IN AIR.

29. The following rule may be used to compute the quantity of heat which will be given off by a current of *hot air* of a given volume per minute, in cooling through any given number of degrees:

Rule 3.—*Multiply together the given volume of the air in cubic feet, the number of degrees through which it is cooled, and the number given in columns 3 and 6 of Table 7, for the original temperature. Divide this product by the original temperature, and the quotient will be the amount of heat given off in heat units.*

EXAMPLE.—A current of hot air having a temperature of 150°, and a volume of 400 cubic feet per minute, is cooled to 65° in passing through a certain room; what amount of heat is given off per minute?

SOLUTION.—From Table 7, the heat contained in 1 cubic foot at 150° is 2.3196 B. T. U. Applying rule 3,

$$\frac{400 \times (150 - 65) \times 2.3196}{150} = 525.78 \text{ B. T. U. Ans.}$$

EXAMPLE.—How much heat will be required to warm 400 cubic feet of air to a temperature of 150°, the temperature out of doors being 10°?

SOLUTION.—The weight of 1 cubic foot at 10° is .08451 pound. Hence, applying rule 2, the number of B. T. U. required to heat 400 cubic feet from 10° to 150° is

$$U = .23751 \times .08451\,(150 - 10) \times 400 = 1{,}124 \text{ B. T. U. Ans.}$$

30. The following table gives, for various temperatures, the weight of air per cubic foot, and the heat units that will be given up per cubic foot, upon cooling, from the original temperature to 0° F. The table is computed on the assumption that the air remains at a constant pressure of 14.7 pounds per square inch.

TABLE 7.

PROPERTIES OF AIR.

Temperature. Degrees F.	Weight per Cubic Foot. Pounds.	B. T. U. Given up by 1 Cubic Foot of Air in Cooling to 0° From	Temperature. Degrees F.	Weight per Cubic Foot. Pounds.	B. T. U. Given up by 1 Cubic Foot of Air in Cooling to 0° From
0	.08635	.0000	75	.07424	1.3225
2	.08597	.0408	80	.07355	1.3975
4	.08560	.0813	85	.07288	1.4713
6	.08523	.1214	90	.07222	1.5438
8	.08487	.1613	95	.07157	1.6149
10	.08451	.2007	100	.07093	1.6847
12	.08415	.2398	110	.06968	1.8205
14	.08380	.2786	120	.06848	1.9518
16	.08344	.3171	130	.06732	2.0786
18	.08309	.3552	140	.06620	2.2013
20	.08275	.3931	150	.06511	2.3196
24	.08206	.4678	160	.06406	2.4344
28	.08139	.5413	170	.06305	2.5458
32	.08073	.6136	180	.06206	2.6532
36	.08008	.6847	190	.06111	2.7577
40	.07944	.7547	200	.06018	2.8587
45	.07865	.8406	210	.05929	2.9572
50	.07788	.9249	220	.05841	3.0521
55	.07712	1.0074	230	.05756	3.1444
60	.07638	1.0885	240	.05674	3.2343
65	.07566	1.1681	250	.05594	3.3216
70	.07494	1.2459	260	.05517	3.4069

VOLUME AND WEIGHT OF AIR.

31. The volume of air and its weight per cubic foot change with the temperature. The following rule may be used to compute the change in volume, the pressure remaining constant:

Rule 4.—*Reduce both the original and the final temperatures to absolute temperatures. Multiply the original volume by the final absolute temperature and divide by the original absolute temperature. The quotient will be the final volume.* Or,

let
V = original volume;
V_1 = final volume;
T = original absolute temperature;
T_1 = final absolute temperature.

Then,
$$V_1 = \frac{V T_1}{T}.$$

EXAMPLE.—What will be the volume of 400 cubic feet of air having a temperature of 150°, when it is cooled to 10°?

SOLUTION.—Applying rule 4,

$$V_1 = \frac{400\,(460 + 10)}{460 + 150} = 308.19 \text{ cu. ft. Ans.}$$

32. At constant pressure the weight of a given volume of air is inversely proportional to its absolute temperature. Let W denote the weight of a volume of air at the absolute temperature T, and W_1, the weight of an equal volume at the absolute temperature T_1; then,

$$W : W_1 :: T_1 : T,$$

or
$$W_1 = \frac{W T}{T_1}, \text{ and } W = \frac{W_1 T_1}{T}.$$

EXAMPLE.—A chimney of 1 square foot area and 120 feet high is filled with hot air at a temperature of 450°; the temperature of the atmosphere is 60°; what is the difference between the weight of the air in the chimney, and the weight of a column of the outside air, of the same dimensions?

SOLUTION.—The volume of the air is 120 cubic feet. The weight of

this volume of external air is (see Table 7) $120 \times .07638 = 9.1656$ pounds. The absolute temperature is $60 + 460 = 520°$. Then,

$$W_1 = \frac{W T}{T_1} = \frac{9.1656 \times 460 + 60}{460 + 450} = 5.2375 \text{ lb.}$$

The difference in weight is, therefore, $9.1656 - 5.2375 = 3.9281$ lb. Ans.

HUMIDITY.

33. The water vapor which pervades the atmosphere exists in the form of a gas independently of the oxygen and nitrogen, but, being a compound gas, its properties differ somewhat from those of a simple gas. Thus, it condenses into water at 212° under a pressure of 14.7 pounds per square inch, while oxygen and nitrogen become liquids only at extremely low temperatures, and under enormous pressures. This vapor, or steam, does not, however, condense entirely and completely into water under atmospheric pressure at the temperature of 212°. A part of it remains in the gaseous condition as true steam, even though its pressure should fall below that of the atmosphere. Steam exists at all temperatures down to zero, and even many degrees below. Thus, at 20° below zero, and under an absolute pressure of .008 pound per square inch, steam still exists. Under natural conditions, the atmosphere is never free from the presence of steam or vapor of water.

The absolute pressure of this steam is very low, but it forces its way into the space which is occupied by the other atmospheric gases, and increases the total tension of the atmosphere by the amount of its own pressure. The aggregate tension of the gases that constitute the atmosphere is shown by the barometer, but no instrument has yet been devised that will show the actual tension of any single one of these gases; therefore, the pressure of the atmospheric steam cannot be measured directly, except by apparatus which cannot be conveniently used outside of the laboratory.

A cubic foot of air will admit or take up the same quantity of steam as a cubic foot of empty space. The weight of the steam will depend solely upon the temperature, provided

that it does not become superheated. The temperature to be considered is that at which condensation begins.

34. The ratio between the quantity of vapor, or atmospheric steam, which is *actually* present in the air, and the *maximum* quantity which it could contain at the temperature and barometric pressure then prevailing, is called the *humidity* of the air.

When the atmosphere contains the maximum quantity of steam that can exist at the temperature of the air, it is said to be *saturated* with moisture. During fair weather the quantity actually present is much below the maximum that the temperature of the atmosphere would permit. When the maximum is reached, the least diminution of temperature or barometric pressure will be followed by the condensation of a part of the vapor. The condensed vapor will be precipitated as dew or rain during summer weather, or as snow in winter time, and in very cold weather it will appear as hoar frost.

MEASUREMENT OF HUMIDITY.

35. There are many substances which absorb moisture from the atmosphere and which swell in volume in consequence. Many attempts have been made to utilize this property, to construct instruments which would indicate the density of the moisture in the air. Until recently not any have been produced which were accurate or reliable. The most successful instrument of this kind is shown in Fig. 1. The indicator hand is attached to a metallic spiral, which is filled with absorbent material. This material absorbs moisture from the

FIG. 1.

air in proportion to the density of the atmospheric vapor, and gives it off again as the density decreases. The material swells in proportion to the amount of moisture which it holds, and thus the spiral which contains it is compelled to bend.

36. The humidity of the atmosphere may be measured by means of two thermometers, one of which is perfectly dry, and the other provided with a wet cloth over its bulb. The cloth is kept moist by a thread or wick leading from a small tank. If the air is not *saturated*, the water will evaporate from the cloth and thus cool the bulb. The rapidity of the evaporation depends upon the relative dryness of the air, and the depression of the thermometer indicates approximately the rate of evaporation from the cloth. This device is called the **wet-and-dry-bulb** thermometer. The scale of humidity is arbitrary, and the operation of the instrument is not sufficiently accurate to be satisfactory.

37. The humidity of the atmosphere may also be measured with accuracy by observing the temperature at which the vapor, or atmospheric steam, will condense. Having found the temperature at which condensation takes place, the pressure of the steam per square inch, and its weight per cubic foot, may be found from Table 8 following. The weight of moisture which is said to be *absorbed* by a cubic foot of air is the weight of a cubic foot of steam at the pressure and temperature thus found.

The instruments commonly used for this purpose are called **dew-point hygrometers.** They operate by gradually cooling a bulb or plate of black glass below the atmospheric temperature. As the temperature falls, a point will be reached at which a deposit of dew begins to appear upon the glass. The formation of dew signifies that the atmospheric vapor which is actually present condenses at the temperature which the glass then possesses. Black glass is preferred, because it readily shows the slightest film of dew.

38. Daniell's hygrometer is shown in Fig. 2. It consists of a glass tube A having a bulb at each end, as shown. The bulb B is made of black glass, and is partly filled with sulphuric ether. The bulb D is empty, and is covered with muslin. A small mercurial thermometer C is enclosed in the tube A, and is so suspended that its bulb extends below the surface of the liquid ether. This thermometer indicates the temperature of the liquid in the bulb B. A second thermometer E, which is attached to the wooden stand, serves to indicate the temperature of the surrounding air. To operate the instrument and obtain a deposit of dew upon the bulb B, a small quantity of ether is poured over the muslin on bulb D. The ether evaporates rapidly, and thus absorbs heat from the bulb and the ether vapor contained in the instrument. As the temperature falls, a point will be reached at which a deposit of dew will appear upon the surface of the bulb B. The dew will remain there until the ether wholly evaporates from the muslin covering of D and the instrument begins to recover its normal temperature.

FIG. 2.

If too much ether is poured upon the cloth-covered bulb D, the instrument may be cooled to such an extent as to depress the thermometer E and cause it to give a false indication of the temperature of the atmosphere.

The temperature shown by the thermometer C at the exact moments when the dew appears and disappears must be carefully noted. If there is much difference in the first

and the second reading, the test should be repeated. When the test is properly made, the average of the two readings may be taken as the correct dew point.

The instrument should be placed in a position where it will be free from the influence of any heating agency. The operator should take care that the warmth of his hands or breath does not affect the thermometers.

39. Having found the dew point, the following rule may be used to compute the relative humidity:

Rule 5.—*Ascertain from Table 8 the weight of a cubic foot of vapor at that temperature; divide this by the weight of a cubic foot of vapor at the temperature of the atmosphere, and the quotient will be the* **relative humidity.**

EXAMPLE.—What is the relative humidity when the temperature of the atmosphere is 70° and the dew point is found to be at 45°?

SOLUTION.—From Table 8, the weight of 1 cubic foot of vapor at 45° is .00048 pound. The weight of 1 pound of vapor at 70° is, from the same table, .00115. Hence, relative humidity $= .00048 \div .00115 = .417$, or 41.7 per cent. Ans.

40. It has been found by observation and experiment that a degree of humidity of from 50 to 70 per cent. should be maintained in dwellings, offices, and audience rooms to secure health and comfort. The air in such rooms is usually maintained at a temperature of 65° to 70° F.; therefore, the *dew point*, as measured by the hygrometer, should be about 55°.

If the dew point is too high, there will be an unpleasant feeling of dampness in the air, the window panes will drip with moisture, and there will be a deposit of dew on all the objects in the room which have a temperature lower than the normal.

41. Rule 6 may be used to find the amount of water which must be evaporated and added to the air supply to maintain any certain degree of humidity.

TABLE 8.

Temperature. Degrees F.	Pressure per Square Inch. Pounds.	Weight per Cubic Foot. Pounds.	Temperature. Degrees F.	Pressure per Square Inch. Pounds.	Weight per Cubic Foot. Pounds.
−30	.0049	.000017	50	.176	.00058
−25	.0063	.000023	55	.212	.00069
−20	.0088	.000030	60	.253	.00082
−15	.0106	.000039	65	.302	.00097
−10	.0135	.000050	70	.358	.00115
−5	.0171	.000063	75	.425	.00135
0	.0216	.000079	80	.502	.00158
5	.0272	.000098	85	.589	.00183
10	.0340	.000121	90	.692	.00213
15	.0423	.000149	95	.809	.00247
20	.0525	.000181	100	.943	.00286
25	.0651	.000222	105	1.094	.00330
30	.0806	.000270	110	1.265	.00380
35	.0998	.000325	115	1.462	.00433
40	.1225	.000400	120	1.682	.00496
45	.1470	.000480	130	2.213	.00640

Rule 6.—*Ascertain the weight of moisture in the air before it is heated, and compute the weight of moisture required to produce the desired degree of humidity in the same weight of air at the temperature at which it is to be used; the difference between the quantities of moisture thus found will be the amount of moisture to be supplied.*

EXAMPLE.—A certain room is supplied with air having a temperature at the registers of 120°, at the rate of 300 cubic feet per minute. The temperature of the room is to be maintained at 70°, and the humidity at 70 per cent. The temperature of the air before entering the heater is 45°, and its humidity is also 70 per cent. What weight of moisture must be supplied to the air-current to secure the desired humidity in the room?

SOLUTION.—It is necessary to know the volumes of the air at the time it is used and before it enters the heater, and these must be computed from the volume and temperature at the register as given. The original volume is 300 cubic feet, and the original temperature is 120° (580° absolute). Applying rule 4, to find the volume at 70° (530° absolute),

$$V_1 = \frac{V T_1}{T} = \frac{300 \times 530}{580} = 274.1 \text{ cu. ft.};$$

and at 45° (505° absolute),

$$V_1 = \frac{V T_1}{T} = \frac{300 \times 505}{580} = 261.2 \text{ cu. ft.}$$

Thus, at the beginning we have 261.2 cubic feet of cold air at 70 per cent. humidity. The weight of that volume of steam at 45° is, from Table 8, 261.2 × .00048 = .1254 pound, and 70 per cent. of this equals .1254 × .70 = .08778 pound, which is the weight of moisture originally contained in the air.

The air when used will have a volume of 274.1 cubic feet and a temperature of 70°. The weight of an equal volume of steam at 70° is 274.1 × .00115 = .3152 pound. The humidity is required to be 70 per cent.; therefore, the total moisture required will be .3152 × .70 = .22064 pound.

Then, .22064 − .08778 = .13286 pound is the amount of moisture, per minute, that must be added to the air-current. Ans.

EVAPORATION AND DRYING.

42. The process of evaporation is used in the arts for increasing the density of liquids by *boiling down*, for drying wet materials, and for cooling purposes.

The vaporization of the liquid may be accomplished by adding more heat to it, or by lessening or removing the atmospheric pressure upon it.

Air may be partially dried by cooling it to a low temperature. The vapor accompanying it will be condensed and thrown down as water, and when the air is afterwards warmed it will be correspondingly dry.

The efficiency of a drying apparatus which uses hot air as the drying medium will depend upon several factors, as follows:

1. The dryness of the air before it is heated.
2. The degree of heat that is given to the air.

3. The amount of surface of wet material from which evaporation can readily take place.

4. The volume of the air-current.

5. The thorough distribution of the fresh dry air over the evaporating surfaces.

6. The promptness with which the moistened air is removed.

If the air is compelled to travel a long distance over wet surfaces, it will evaporate moisture freely during the first part of its course, less in the middle, and almost none at the end of the course. It is, therefore, advisable that the air-currents be so arranged that none of them are obliged to travel over a course of undue length.

The drying rooms of laundries are usually deficient in circulation of air, although well supplied with heat. Heat alone cannot dry the clothes; the moist air must be removed as fast as it is moistened. The humidity of the outgoing air should not be allowed to approach *saturation*, but should be kept as low as practicable.

FRICTION OF AIR IN PIPES AND FLUES.

43. The resistance which is encountered by air and other fluids in moving through pipes, flues, and conduits is usually spoken of as *friction*, although the term, as thus used, is not strictly accurate.

The resistance arises from several causes:

1. *Skin friction*, which is the actual friction of the fluid against the surfaces over which it passes.

2. The abrupt changes of direction of the current, at elbows and tees.

3. The movement of one part of the current upon another, in passing around curves.

4. The abrupt changes in velocity, which occur at pockets and enlargements.

5. The formation of whirls or eddies.

6. The interference of currents.

44. Skin Friction.—The resistance due to skin friction varies (1) directly as the length of the pipe or flue; (2) inversely as the diameter or length of a side; (3) directly as the square of the velocity. Hence, other things being equal, the pipe should be as short as possible; its diameter should be as large as possible, and the quantity passing through it in a given time should be as small as circumstances will permit. The last consideration is the most important of all, since, if the quantity passing through a given pipe is doubled, the velocity is also doubled, and the resistance is increased 2^2, or 4 times.

The condition of the pipe itself, whether smooth or rough, also affects the force required to overcome the friction, a smooth pipe offering less resistance than a rough one. Hence, metal pipes are to be preferred, in this respect, to brick conduits. A polished pipe offers less resistance than a smooth one not polished. A pipe or flue having its inside covered with soot offers much greater resistance than a similar pipe that is clean.

45. Resistance From Changes of Direction.—When a current of air encounters an obstacle, the particles composing it are compelled to deflect from their normal direction

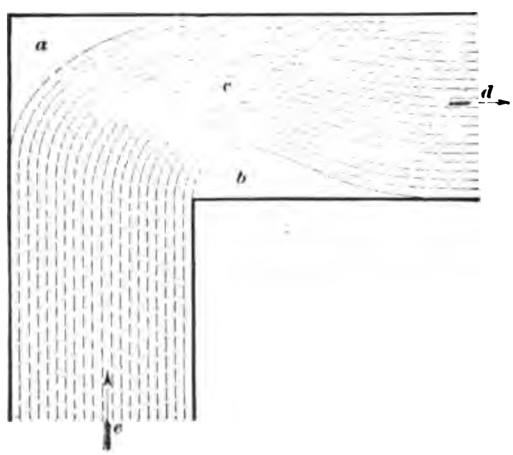


FIG. 3.

and to move sideways sufficiently to pass by the obstruction, consequently the current loses some of its kinetic energy.

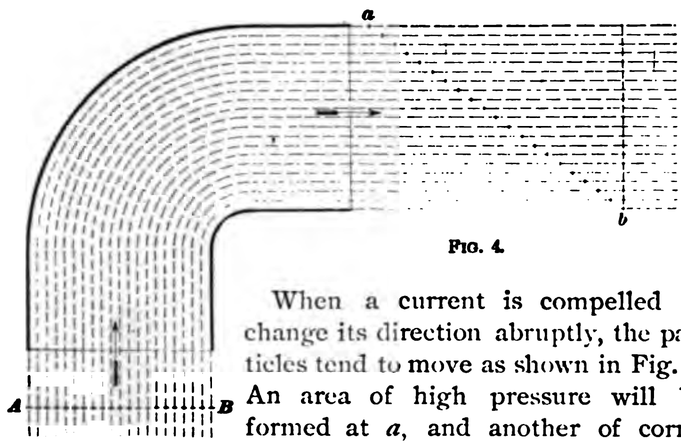


FIG. 4.

When a current is compelled to change its direction abruptly, the particles tend to move as shown in Fig. 3. An area of high pressure will be formed at *a*, and another of correspondingly low pressure at *b*. The effective area of the pipe or conduit will be reduced at *c*, and the velocity of the fluid will be greater at that point

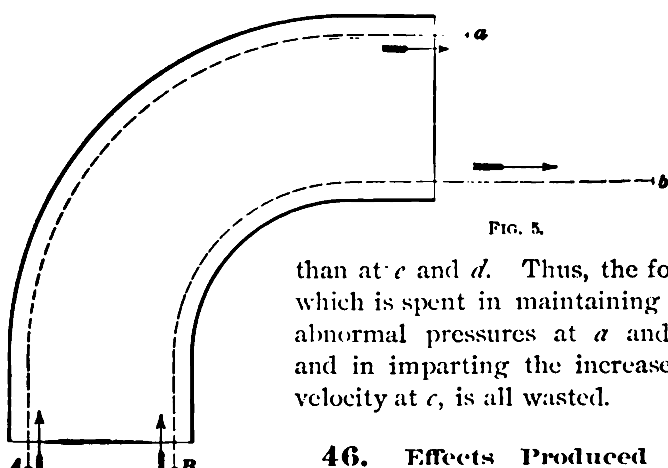


FIG. 5.

than at *c* and *d*. Thus, the force which is spent in maintaining the abnormal pressures at *a* and *b*, and in imparting the increase of velocity at *c*, is all wasted.

46. Effects Produced by Curves.—If the turn is less abrupt, as in Fig. 4, the waste of energy is considerably reduced. The tendency to form high and low pressure areas,

as in Fig. 3, is nearly destroyed. But the particles of the fluid are still compelled to slide over one another. Thus, the particles at *A* and *B* will reach the points *a* and *b*,

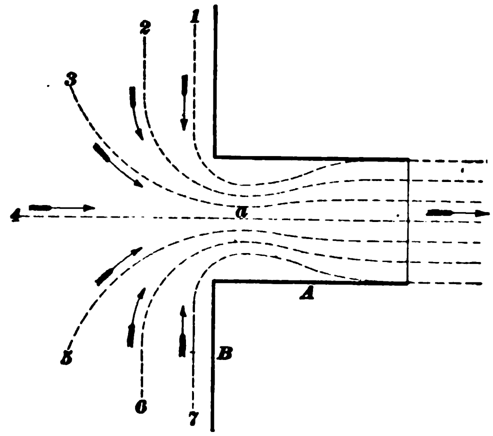


FIG. 6.

respectively, at the same time, if they travel equal distances in equal time. The power which is expended in sliding the particles of fluid upon one another is wasted.

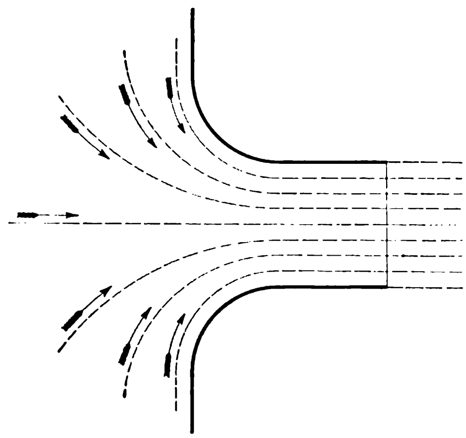


FIG. 7.

This loss cannot be avoided, whether the turn be made sharply, as in Fig. 3, on a small radius, as in Fig. 4, or on a long radius, as in Fig. 5. But the *time* which is afforded for making the change of direction (the velocity being the same in each case) is much greater in Fig. 5 than in either of the others. The force which is required to deflect a moving body from its normal path is inversely proportional to the

square of the time in which the change of direction is made. Hence, if the change of direction is made in 2 seconds in Fig. 4, and in 4 seconds in Fig. 5, then $4^2 \div 2^2 = 4$ times as much force will be required when turning the curve of shorter radius.

47. Interference of Currents.—The effect of *opposing* currents is shown in Fig. 6. This illustrates the formation of what is called the **contracted vein.** The branch *A* is attached at right angles to a tank or reservoir *B*. It will be seen that the particles which move on the lines *1* and *7* would collide if their motion were continued, and would destroy each other's motion. Their energy is spent, however, in deflecting the other parts of the current somewhat out of their course. The effect of the opposition of the various currents is to reduce the effective diameter of the stream at *a* to less than the diameter of the branch *A*. Consequently, the amount of fluid which will be delivered through the branch will be less than it should be. The trouble may be remedied by providing the branch with a mouthpiece which is curved so as to properly guide the parts of the current, as shown in Fig. 7. The branch will then discharge to its full capacity.

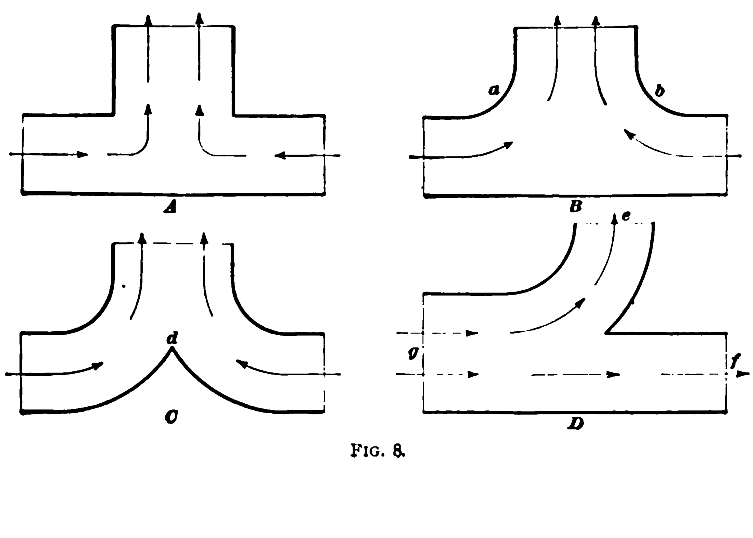


FIG. 8.

CONDUITS AND BENDS.

48. Currents of fluid should always be guided in such a manner that they do not interfere or oppose one another's motion. The resistance offered by opposing currents in the common **T** connection, as shown at *A* in Fig. 8, is so great that its use should never be permitted. By making the corners *a* and *b* round, as shown at *B*, the evil is lessened, but only to a small degree.

The effect of the opposing currents may be reduced to a minimum by interposing between them a dividing ridge or partition *d*, as in the **twin elbow** *C*. If the current moves in the opposite direction to that shown by the arrows, the form *C* will still be preferable to *B* or *A*.

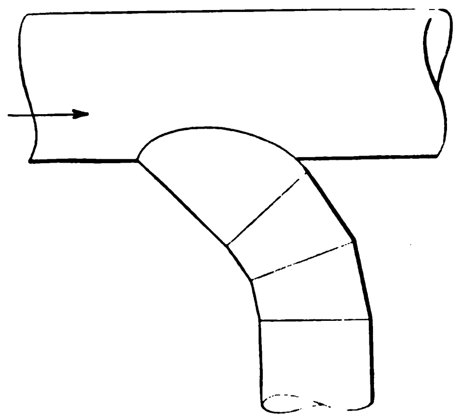


FIG. 9.

49. When the flow in one of the branches *f* is to continue in the same direction as in the main *g*, the other branch should be curved as shown at *e*, in the style *D*.

When a branch is to be taken from a main, as in Fig. 9, it should be attached at the smallest practicable angle. If the situation will not permit the form shown, and the branch must be joined at a right angle, then the connection should be made with a *gusset*, as at *a*, Fig. 10.

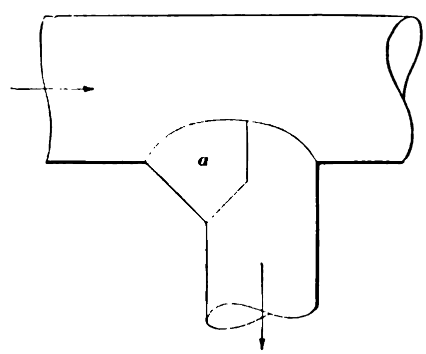


FIG. 10.

50. The connection of the flat wall pipe to the round pipe, shown in Fig. 11, is a faulty one. The change of

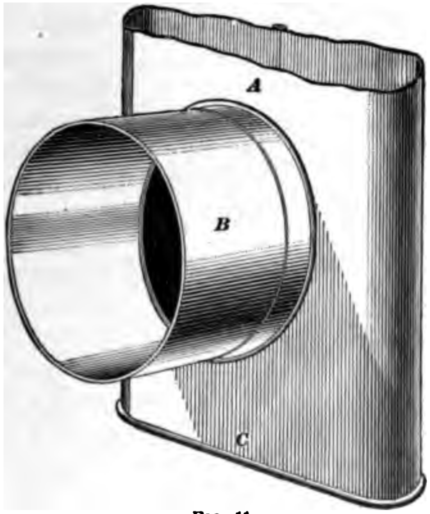


FIG. 11.

direction which the current of air is required to make, is very abrupt; the dead end C will also operate to retard the

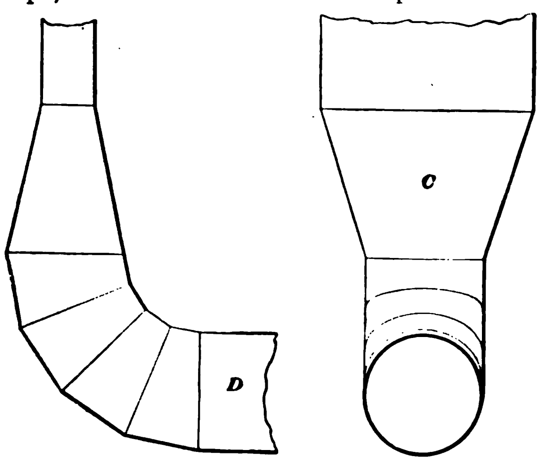


FIG. 12.

current by forming an eddy at that point. The connection should be made similar to that shown in Fig. 12.

SPLITTING AIR-CURRENTS.

51. Fig. 13 shows the proper manner of dividing a main current into three branches so as to supply independent air flues. If the partitions A and B were absent, the greater part of the current would continue its motion until it was deflected by the side C. In that case, the flue D would receive a larger proportion of the current than either of the others, and the supply to the flue F would be quite insufficient.

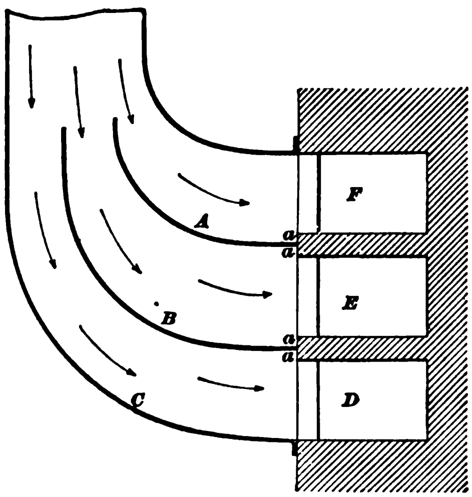


FIG. 13.

A proper supply of air to each flue may be insured by adjusting the partitions A and B in such a manner that they

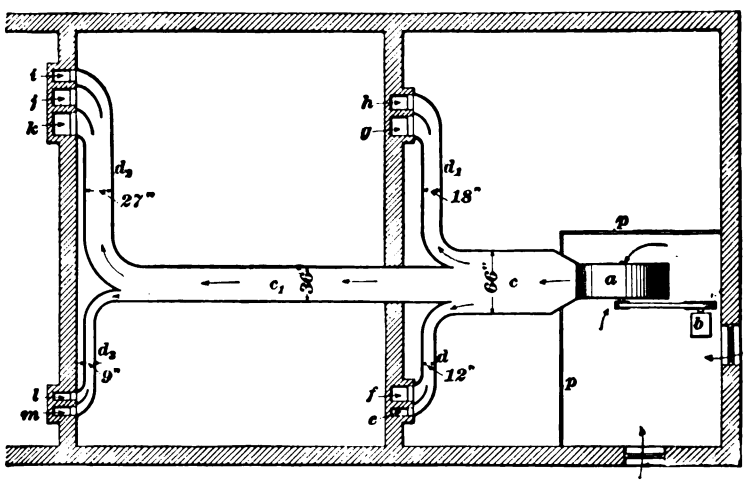


FIG. 14.

will intercept the desired proportions of the main current *before* any change is made in its direction.

52. Fig. 14 illustrates the proper method of splitting up a main air-current into several smaller ones, and of subdividing these so as to supply a large number of vertical ducts. The method of proportioning the various branches so as to supply all the ducts with air at a uniform pressure, or otherwise, as desired, will be explained in a later section.

SHAPE OF AIR PIPES.

53. The shape which should be given to an air pipe or conduit depends upon several considerations.

1. To carry a *given volume* of air, the circular form has the following advantages: (*a*) It requires less material to construct it. (*b*) It offers less resistance from skin friction. (*c*) It requires but little bracing to maintain it in proper shape.

2. To carry the *greatest volume* in the least space, the square form should be used.

For example, if it be required that a pipe should have an area of 254 square inches, it will be found that the desired area will be afforded by a round pipe 18 inches in diameter, or a square pipe 16 in. × 16 in. The circumference of the round pipe will be $56\frac{1}{2}$ inches, while that of the square pipe will be 64 inches. But the square pipe may be run through a space which is 2 inches less each way than that required for the round pipe of *equal capacity*.

MECHANICAL EFFECTS OF WIND.

54. The mechanical effects of the wind which are of interest in the heating and ventilation of buildings are:

1. The increase of the atmospheric pressure upon the windward side of buildings, and the corresponding decrease upon the opposite side.
2. The increase of the draft of chimneys and flues.
3. The reversal of currents, called *blow-downs*.

4. The formation of eddies and whirls, which deposit dust and snow in undesirable places.

5. The increase of evaporation and the consequent drying and cooling effects.

55. When the wind blows against a building, the pressure of the air upon the windward side will be greater than upon the leeward side. The air which is within the building will tend to flow out through every crevice and flue into the area of low pressure which exists upon the leeward side of the building. If, at the same time, there is no leakage of air into the building from the windward side, the atmospheric pressure within the building will fall slightly. But, if there are any openings or crevices upon the windward side, the air will flow from the area of high pressure upon the outside to the inside of the building, where the pressure is at, or below, the normal.

If the leeward side of the building is tight, and the wind can leak through the windward side only, then the pressure within the interior of the building will be slightly increased. This extra pressure will ooze out through every crevice upon the leeward or neutral sides of the building. It will escape through the ventilating flues also. Thus, a considerable amount of air will pass through the building notwithstanding the tightness of the leeward side.

If, on the contrary, the windward side is tight and the leeward side is leaky, only a small leakage will occur, and that will be from the interior toward the leeward side.

Thus, the amount of air which will be driven through a building by the wind (leaving out of consideration the effects upon chimneys, etc.) will depend mainly upon the tightness of the *windward* side, and not upon the condition of the leeward side.

The pressure which is exerted by the wind per square foot of obstructed area is greatly modified by the shape of the surface.

Thus, the pressure upon a sphere, or a hemisphere with convex side towards the wind, is about one-half of that upon a flat surface of equal diameter.

EFFECTS OF WIND UPON CHIMNEYS.

56. When the wind blows horizontally, as in Fig. 15, the air which is compressed at A flows up over the edge of the chimney and follows the path of the arrows a and b. This current deflects the wind somewhat, as shown by the arrows c and d, and lifts it above the leeward edge of the chimney. An opportunity is thus given for the chimney gases (which are shown by feathered arrows) to pass over the edge of the chimney into the area of low pressure at B. As the velocity of the wind increases, the pressure at B becomes less, and the chimney draft is augmented correspondingly.

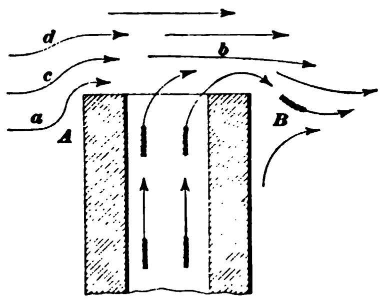


FIG. 15.

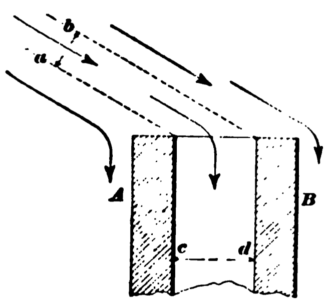


FIG. 16.

If the wind blows upwards, the area of low pressure is formed close to the top of the chimney, and the escape of the chimney gases is greatly facilitated. But, if the wind blows downwards, as in Fig. 16, the escape of the chimney gases is cut off, and, unless there is sufficient pressure behind them to deflect or lift the wind at the mouth of the chimney, a *back draft*, or *blow-down*, will be produced. All that part of the wind which is included between the dotted lines a and b tends to blow downwards in the chimney; but its pressure is reduced as soon as it enters the chimney, because it is then compelled to fill a larger area. Thus, the downward pressure which the wind will exert in the chimney may be found by multiplying the wind pressure by the perpendicular distance between a and b, and dividing that product by the width $c\,d$ of the chimney. If this quotient exceeds the upward pressure of the hot gases, then a blow-down will occur.

57. The beneficial effect of the ordinary horizontal winds upon the draft of a chimney may be increased by means of the circular **deflector** *C*, shown in Fig. 17. That part of the wind which is intercepted by the curved surface of *C* is deflected strongly upwards and operates to lift the main current of wind well above the top of the chimney. Thus, the chimney gases are given a good opportunity to escape over the leeward edge, as indicated by the arrows.

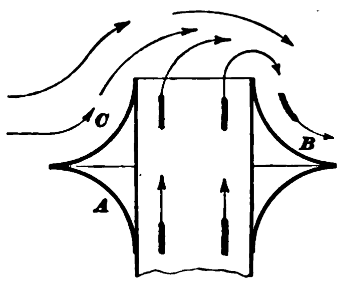


FIG. 17.

COWLS.

58. The term **cowl** is applied in a general way to all apparatuses or fixtures which are placed over the top of chimneys or ventilating flues, etc., to aid the draft. They serve to protect the ascending current of hot gases within the flue from the influence of contrary wind currents, which might oppose or even overbalance and reverse it. They also serve to facilitate the escape of the warm gases into the area of lower pressure, which always exists upon the leeward side of a chimney or ventilating shaft while the wind is blowing. During calm weather, a cowl always obstructs the draft somewhat.

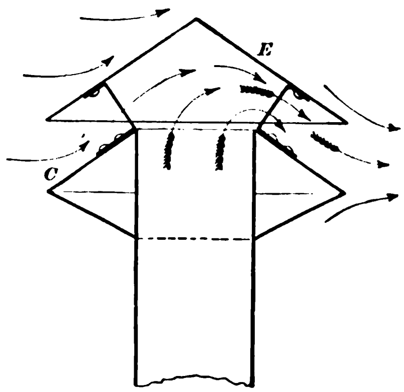


FIG. 18.

A common form of cowl is shown in Fig. 18. It is essentially composed of a conical top *E*, supported by three or four legs on a frustum of a cone or deflecting collar *C*. The diameter of the cone should be from 2 to $2\frac{1}{2}$ times that

of the pipe to which it is attached, and the distance from the edge of the pipe to the under surface of the cone should not exceed one-half the diameter of the pipe.

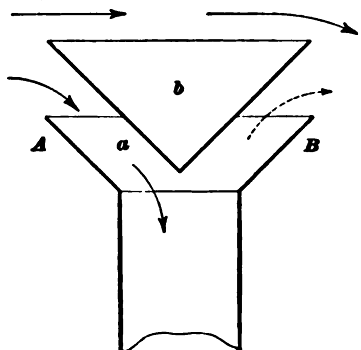


FIG. 19.

59. The wind may be utilized to drive a current of air downwards in a pipe by an arrangement similar to that shown in Fig. 19. The pipe is provided with a funnel *a*, and a cone *b* having its apex downwards. A part of the wind which strikes the cone will be deflected downwards into the pipe, as shown by the arrows. But there will be an area of low pressure at *B*, and a part of the contents of the pipe will escape into it, as shown by the dotted arrow; consequently, some of the air will be lost. This device is called an **induction,** or **blowing,** cowl.

60. Automatic cowls are commonly made as shown in Fig. 20. An elbow *a*, having a funnel mouth *b*, is mounted so as to turn freely upon a central spindle *c*, as shown. The vane *v* catches the wind, and operates to keep the funnel always turned away from the wind. This device for aiding the draft of chimneys is very effective, but it is difficult to maintain in good working order. The pivot corrodes so rapidly that the elbow is apt to stick fast and fail to operate.

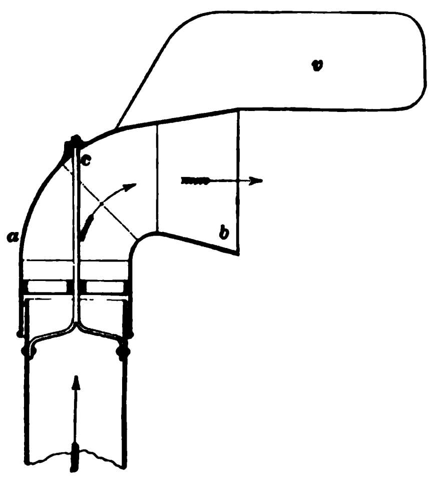


FIG. 20.

This apparatus may also be used to produce a downward cur-

rent, for ventilating purposes, by changing the vane *v* so that it will hold the funnel towards the wind, instead of away from it.

61. The cowl shown in Fig. 21 is provided with a blowing cone *a*, which causes the cowl to operate as an ejector. The cone gathers the wind which it catches into a small

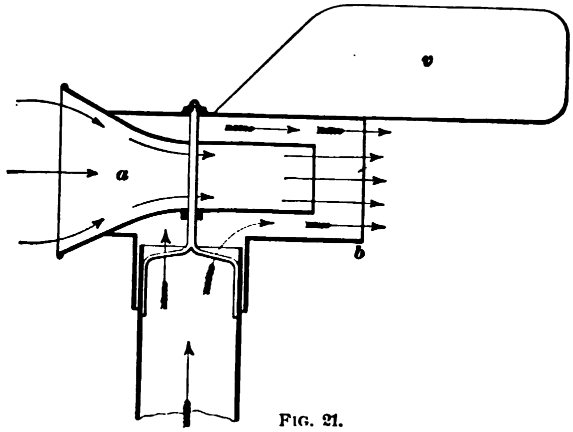


FIG. 21.

current of high velocity; and, as this current emerges into the mouth of the elbow or tube *b*, it communicates its velocity to the gases at the top of the chimney, forcing them ahead with it, and creating a partial vacuum around the cone. The gases from below then rush upwards with an augmented velocity, owing to the increased difference of pressure. This apparatus is called an **automatic eduction** cowl.

COMBUSTION AND FUELS.

NATURE OF COMBUSTION.

62. Elements and Compounds.—Every body, every mass of matter, is either an *element*, a *compound*, or a *mixture*. Iron, silver, sulphur, and oxygen are elements; water, wood, lime, and carbonic acid are compounds.

A compound may be decomposed or divided into separate substances. For example, if an electric current is passed

through water, the water slowly disappears, and two gases are formed. These gases are entirely unlike, and neither resembles the water from which it was produced. Likewise, lime can be divided into two other substances, calcium and oxygen. Any substance which can thus be decomposed or divided into other substances, is called a **compound.**

There are substances, however, which have never been decomposed into other substances. By no known process can sulphur be separated into other substances; the same is also true of iron, gold, arsenic, and many other substances. Substances which have never been decomposed are called **elements.**

63. Combustion *is very rapid chemical combination.* The atoms of some of the elements have a very great affinity, or attraction, for those of other elements, and when they combine they rush together with such rapidity and force that heat and light are produced. Oxygen, for example, has a great attraction for nearly all the other elements. An atom of oxygen is ready to combine with almost any substance with which it comes in contact. Oxygen has a particular liking for carbon, and whenever these two elements come in contact at a sufficiently high temperature they combine with great rapidity. The combustion of coal in the furnace of a boiler is of this nature. The temperature of the furnace is raised by kindling the fire, and then the carbon of the coal begins to combine with oxygen taken from the air. The combination is so rapid and violent that a great quantity of heat is given out.

The elements which enter into combustion are oxygen and, usually, either carbon or hydrogen. Coal, wood, and other fuels are composed almost entirely of these three elements. *Combustion is, therefore, the rapid chemical combination of oxygen with either carbon or hydrogen, or both.*

64. When carbon and oxygen combine they form a gas called *carbon dioxide*, which is denoted by the symbol CO_2; when hydrogen and oxygen combine they form *water* (H_2O). These are called the **products of combustion.** When, as is ordinarily the case, the oxygen is obtained from

the air, the nitrogen of the air passes into the furnace along with the oxygen. It takes no part in the combustion, and passes off up the chimney with the CO_2. Hence, *nitrogen* is also a product of combustion in air.

There is one other case that may occur: the combustion of carbon may not be complete. If insufficient air or oxygen is supplied to the burning carbon, it is possible for the carbon and oxygen to form another gas, **carbon monoxide,** or CO, instead of carbon dioxide (CO_2).

The combustion of a pound of carbon to form CO, of course, requires only half of the oxygen that would be necessary to form CO_2. This is because in CO gas 1 atom of carbon seizes 1 atom of oxygen instead of 2 atoms. To burn a pound of carbon to CO_2 requires 11.6 pounds of air. To burn it to CO would, therefore, require but 5.8 pounds of air.

65. The quantity of air required in practice to properly burn coal at different rates of combustion, per square foot of grate surface per hour, is about as follows:

TABLE 9.

Rate of Combustion per Square Foot of Grate. Pounds of Coal per Hour.	Air Required per Pound of Coal.	
	Weight. Pounds.	Volume at 62°. Cubic Feet.
4	23.2	304.85
8	20.2	265.45
12	17.5	230.00
16	15.1	198.43
20	13.0	170.83

There is little or no difference in the amount of air required, per pound, to burn anthracite or bituminous coal.

FUEL.

66. In selecting a fuel for any certain service, the characteristics of each variety should be well considered. The value of a fuel depends primarily upon the amount of

heat which it will give off during combustion, but this is modified by the amount of labor and care required in its use.

The following points should be studied carefully:

1. The amount of labor required for feeding and cleaning the fires.

2. The amount of the ashes, and the labor or cost of removing them.

3. The labor required for cleaning out the soot and dust from the boiler and its settings.

4. The liability to produce smoke, and the cost of the necessary arrangements to prevent it.

5. The extent and cost of the storage required for the fuel, and for the ashes.

6. The cost of the fuel, delivered upon the premises.

If the ash is easily fusible it will melt and run together, forming large blocks of *clinkers*. This will add greatly to the labor required to keep the fire in good order.

The practice of burning a *mixed fuel*, that is, a mixture of coarse and fine coal, is a wasteful one. The small pieces burn to ashes before the large lumps are completely consumed.

67. Storage of Fuel.—Coal of all kinds should be carefully protected from the weather. When it is alternately wet and dry, it is slowly oxidized, and the damage is proportional to the richness of the coal in volatile matter. Even hard anthracite suffers considerable damage by exposure.

The space required for the storage of fuel, in cubic feet for each thousand pounds of material, is about as follows:

Anthracite coal, prepared "stove" size	18 cubic feet.
Bituminous coal, prepared "stove" size	20 cubic feet.
Coke	34 cubic feet.
Cord wood	38 cubic feet.
Petroleum, in barrels	18 cubic feet.

CHIMNEYS.

68. Apparently the area of a chimney may be found by dividing the volume of the chimney gases, in cubic feet per minute, by the theoretical velocity due to their temperature. But no reliable rule can be given for this purpose, because a large proportion of the draft pressure is expended in forcing the air through the fire, and in overcoming friction, etc. in the flues leading to the chimney. The velocity of the gases in the chimney is thereby reduced to 50, or even 25, per cent. of the theoretical velocity. It is necessary, therefore, to depend for information upon the data secured by tests and actual service.

The rate of combustion of anthracite coal, per square foot of grate per hour, which may be attained in practice with various heights of chimneys, is shown in the following table. The area of the chimney required, per pound of coal thus burned, is also given for each height. This is based upon the proportion of 1 square foot of chimney area to 8 square feet of grate surface.

TABLE 10.

SIZE OF CHIMNEYS.

Height of Chimney. Feet.	Rate of Combustion. Pounds of Coal per Hour per Square Foot of Grate Area.	Area of Chimney per Pound of Coal Burned per Hour. Square Feet.
40	11.6	.0108
50	13.1	.0095
60	14.4	.0087
70	15.7	.0080
80	16.8	.0074
90	17.9	.0070
100	19.0	.0067
110	19.9	.0064
120	20.8	.0061
130	21.7	.0059
140	22.5	.0057
150	23.4	.0055

The size of a chimney should be adapted to the *maximum* work that it may ever be called upon to do. Chimneys for domestic heating apparatus, etc., which are built into the walls of a house, should be made of generous dimensions, so as to avoid all possible overheating, and the consequent danger from fire.

HEATING AND HEATING APPARATUS.

HEATING AIR.

69. Air cannot be heated by radiation; it can only be heated by *conduction*—that is, by direct contact with heated surfaces; or by currents of hot air—that is, by *convection*.

The number of heat units transmitted per hour from 1 square foot of surface, for each degree of difference in temperature between the fluids upon the opposite sides of the heating surface, is called the **coefficient of transmission** of that heating surface.

70. In experimenting with the condition of heating surfaces, it is found that, with surfaces of various kinds, the rate of emission is about as follows, the total emission from a new cast-iron plate having a natural surface, as cast, being taken as 100:

Cast iron, new	100
Cast iron, rusty	103
Wrought iron, ordinary or "black"	93
Wrought iron, bright, but not polished	72
Surface covered with lampblack, dull	106
Surface covered with white-lead powder, dull	106

It is found, also, that the rate of emission is affected, by painting or bronzing, about as follows, the amount given off without paint being taken as 100:

Two coats of asphaltum paint	106
Two coats of white-lead paint, dull	109
Rough bronzing	106
One coat of glossy, white paint	90

This last item shows the effect of a glossy or polished surface in reducing the emission of heat.

FORMS OF HEATING SURFACES.

71. Heating surfaces which have no projections of any kind are classified as **plain surfaces,** while those having ribs, knobs, pins, or other projecting parts are called **extended surfaces.**

The object sought in the construction of extended surfaces is to make the area of the emitting surface greater than that of the absorbing surface. By this means, heat may be transferred from a fluid which gives it off readily to one which takes it up slowly, with but little decrease in temperature of the heat-transmitting surfaces.

72. The effectiveness of a radiator will depend, to a considerable extent, upon the direction in which the air is moved over the heating surfaces. Fig. 22 shows a vertical tube standing in still air. The tube is heated by steam, and its surface has a temperature which is practically uniform throughout. The air, which is warmed at the lower end of the tube, flows upwards and envelops the upper part in a current of hot air. The emission of heat will be slower from the upper part of the tube than from the lower part, because the difference in temperature between the air and metal is less.

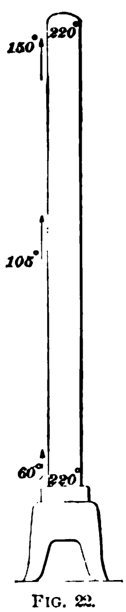


FIG. 22.

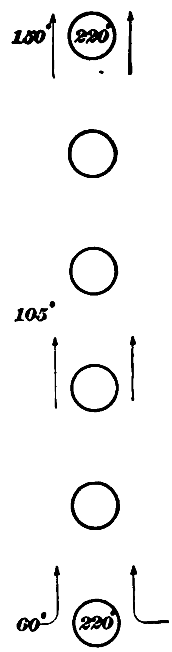


FIG. 23.

A similar loss of efficiency occurs in a common coil of horizontal pipes laid vertically over one another, as shown in Fig. 23. The upper pipes are enveloped in the warm air which has been heated by the lower pipes.

The maximum efficiency can be attained by placing the

coil or radiator in a horizontal position, as indicated in Fig. 24. Each tube will then operate upon air of equally

FIG. 24.

low temperature, and consequently the rate of emission will be greater than in the cases shown in Figs. 22 and 23.

73. If horizontal radiator tubes are grouped together in large numbers, the efficiency of the tubes in the interior of the group will be much less than that of the outside tubes, because the access of cold air to them is practically cut off, and they can act only upon air which has been already warmed by the outer tubes.

Their efficiency is still further reduced by the fact that nearly all of the heat which they emit by radiation is intercepted and cut off by the outer tubes.

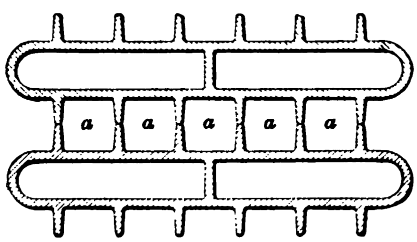


FIG. 25.

If the inner tubes of a group can be fully supplied with cold air, in some manner, they will be as useful as the outer tubes. When forced circulation is employed, there is little difficulty in driving the cold air over all the tubes; but, with natural draft only, it is necessary to modify the shape and arrangement of the tubes to secure a satisfactory result.

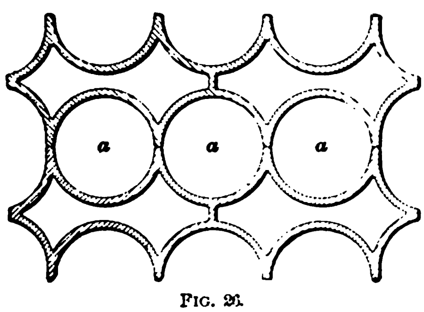


FIG. 26.

Figs. 25 and 26 show varieties of radiator tubes which are so shaped that, when they are assembled in a group, they enclose vertical air

flues, as shown at *a*. The bases of the tubes are set high enough above the floor to permit an abundant flow of air into the flues at the bottom. Radiators constructed in this manner are called **flue radiators.**

RADIATORS.

CONSTRUCTION OF RADIATORS.

74. Radiators which are made of ordinary steam pipes and fittings, as shown in Figs. 27 and 28, are usually called **coils.** Coils are also made of continuous pipes, which are bent and curved to a great variety of shapes.

75. The **continuous flat coil,** Fig. 27, is made of straight pipes connected by return bends. The circulation

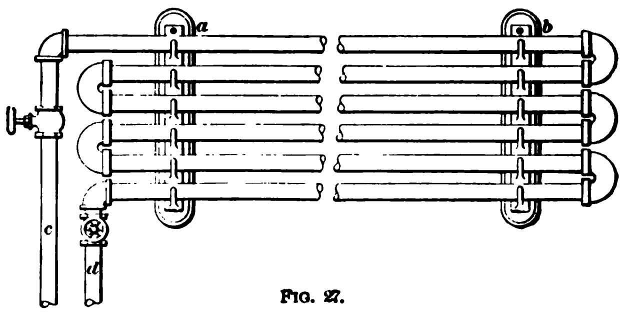


FIG. 27.

of the fluid through it is direct and certain, and it is regarded as the most efficient form of radiator in common use.

76. A **miter coil** is shown in Fig. 28, the pipes being connected between two manifolds *a* and *b*. The steam moves forward simultaneously through all the pipes; its velocity, therefore, will be one-sixth of the rate in a single pipe, as in Fig. 27. The circulation is likely to be uneven, because the fluid entering at *g* will naturally flow by momentum to the end of the manifold, and will enter the pipe *e* in greater quantity than into the pipe *f*. The path through

ec is shorter than through *fd*, and, the friction being less, the main part of the current will go that way.

It will be noted that all the horizontal pipes are connected to the manifold *a* by means of elbows and vertical pipes. This must always be done, so as to permit the several pipes to expand independently, as their differing temperatures may require. The vertical pipes will bend or yield sufficiently to accommodate the difference in expansion.

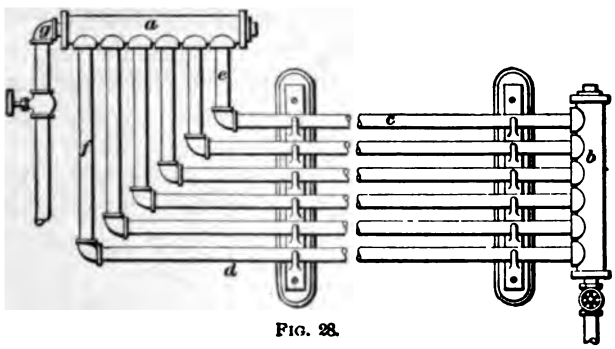


FIG. 28.

If a coil is made by connecting two manifolds, parallel to each other, it will be difficult to keep it steam-tight. The pipes will expand unequally and will crack or break some of the connections.

When several flat coils are grouped together, the construction is called a **box coil.**

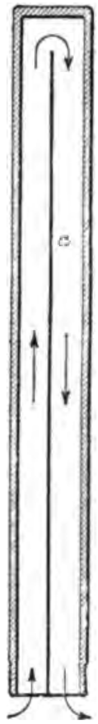
77. The size of pipe used for constructing coils depends mainly upon the pressure of steam to be employed, length of the coil, and the force of the circulation through it. The sizes in common use are from 1 inch to 2 inches.

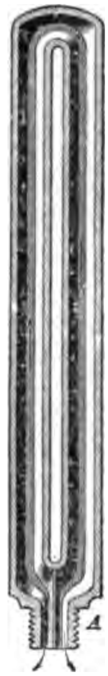
Pipe coils must be arranged so all of the water which is condensed within them may flow easily towards their outlets.

78. Fig. 29 shows a tube called the **Nason tube.** It connects to the radiator base by a single screw joint, and is divided into two passages by means of a sheet-iron plate *a* which extends nearly to the top of the tube, as shown.

The steam rises on one side, passes over the end of the plate, and descends on the opposite side of the tube. Each tube thus forms a complete *loop*, or circuit.

79. Fig. 30 shows the **Bundy loop,** in longitudinal section at A and cross-section at B. This, also, is screwed into a cast-iron radiator base of suitable shape, and the steam moves up one branch of the tube and down the other.





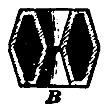


FIG. 29. FIG. 30.

80. The **Detroit loop** is shown in Fig. 31. Each loop is complete in itself, and requires no base or supply chamber. They are connected together, in any number desired, by means of nipples a and c. When the connection at the top is not desired, the loops are bound together by a bolt which passes through the space between them, shown in the end view.

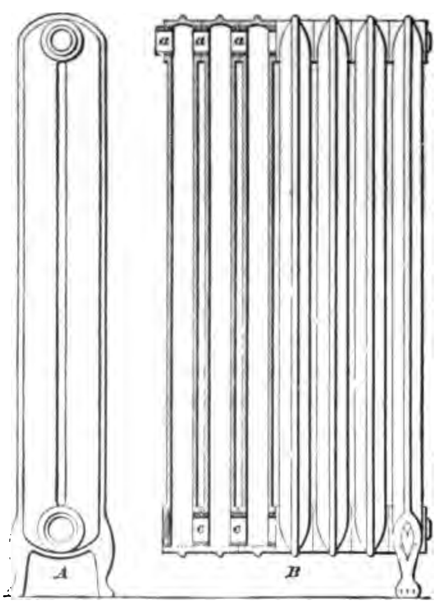


FIG. 31.

The construction of this class of loops is often varied so that they comprise three or even four parallel tubes. They are also modified so as to form flue radiators.

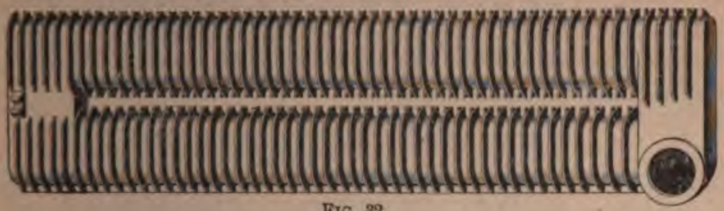


FIG. 32.

81. Fig. 32 shows an **extended surface loop** which is especially designed for indirect heating. These loops, or *sections*, are coupled together by nipples, as illustrated at *a* and *c* in Fig. 31.

Another variety which is in extensive use for indirect heating is shown in Fig. 33. This is called a **pin radiator,**

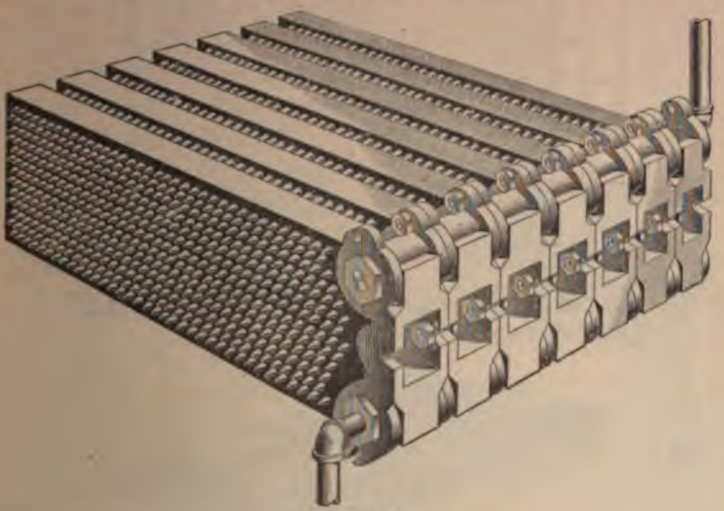


FIG. 33.

because the extensions of the heating surface are made in the shape of small conical pins. The sections may be coupled at both top and bottom, as shown.

82. Radiators of the kind shown in Fig. 31 should have supports at short distances apart, particularly when the

loops are not connected together on top. If the radiator is over 3 feet long, the middle loop should be provided with feet, and, in the case of very long and low radiators, the supports should not be more than 30 inches apart. Every foot should bear firmly on the floor, to prevent sagging of the radiator and consequent straining or rupture of the joints, or cracking of the castings.

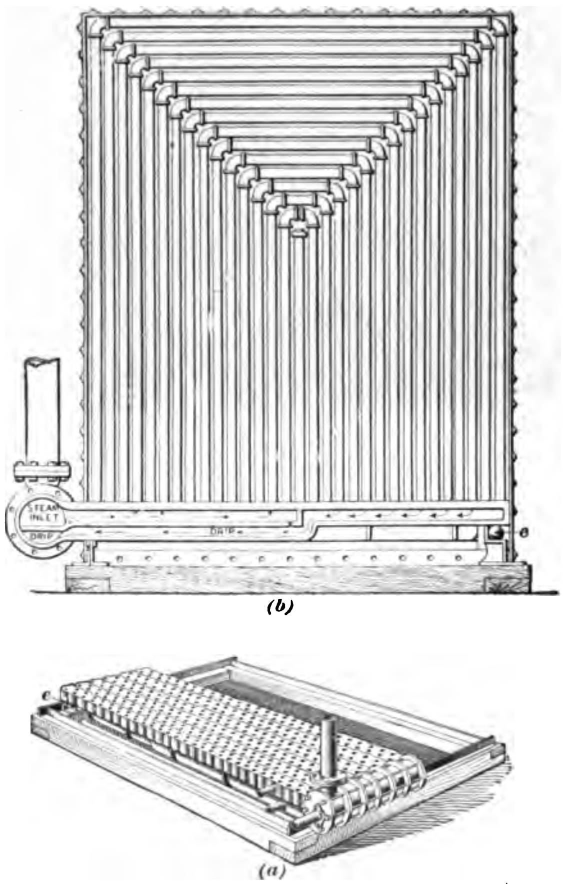


FIG. 34.

83. The radiators which are commonly used for heating air on a large scale, where forced draft is employed, are

usually constructed as shown in Fig. 34. The tubes are of 1-inch steel or wrought-iron pipe, and are connected at the top by cross pipes, instead of return bends, thus preventing all distortion by unequal expansion.

The tubes are *staggered*, so that those in one row stand opposite the spaces between the tubes in the preceding row. By this means, all parts of the air-current (which passes through horizontally) are brought into contact with the tubes and are thoroughly heated.

The *base sections*, or *headers*, are coupled together at one end by flanged joints. The group of base sections may be divided into two or more parts, each of which may have an independent supply and return pipe. Thus, the whole heater may be used, or only a part of it, as desired. The sides of the sections are corrugated so that they interlock and leave no open spaces between them. The farther end of each section rests upon a roller *e*, so that they can expand and contract freely without straining. The course of steam through the heater is shown by arrows.

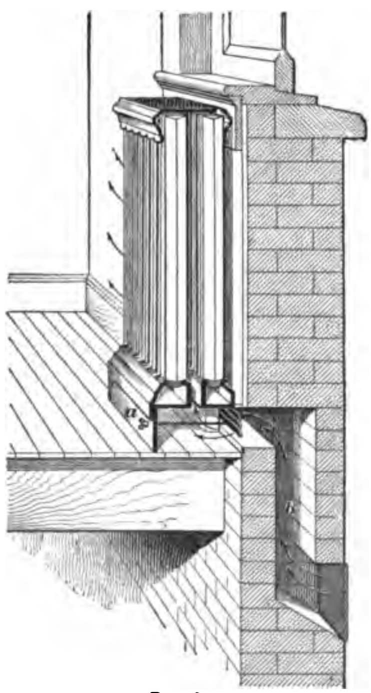


FIG. 35.

84. The ordinary varieties of vertical-tube radiators may easily be adapted to **direct-indirect heating.** The mode of applying a direct radiator of the Nason or Bundy type to that purpose is shown in Fig. 35. The base of the radiator is enclosed by plates *a*, so that the fresh air, which comes in through the flue *b*, is compelled to pass upwards and between the hot tubes before it can escape into the room.

Flue radiators may be applied in a similar manner by enclosing the base and compelling the fresh air to pass up the flues.

EMISSIVE CAPACITY OF RADIATORS.

85. The following general conclusions are deduced from the results of extensive experiments and tests of radiators:

The various materials used for radiators do not show any

TABLE 11.

RADIATORS—VERTICAL TUBE, PRIME SURFACE.

Difference in Temperature. Degrees F°.	Vertical Tubes, Massed. 40 Inches High. B. T. U.	Vertical Tubes, Massed. 24 Inches High. B. T. U.	Vertical Tubes, Single Row. 40 Inches High. B. T. U.	Vertical Tubes, Single Row. 12 Inches High. B. T. U.
50	1.29	1.54	1.46	2.01
60	1.33	1.58	1.50	2.06
70	1.36	1.62	1.54	2.12
80	1.39	1.66	1.58	2.17
90	1.41	1.70	1.62	2.22
100	1.46	1.74	1.65	2.27
110	1.49	1.78	1.69	2.32
120	1.52	1.82	1.73	2.38
130	1.56	1.86	1.77	2.43
140	1.59	1.90	1.81	2.48
150	1.63	1.94	1.85	2.53
160	1.66	1.98	1.88	2.59
170	1.69	2.02	1.92	2.64
180	1.73	2.06	1.96	2.70
190	1.76	2.10	2.00	2.75
200	1.80	2.14	2.03	2.80
210	1.83	2.18	2.07	2.85
220	1.86	2.22	2.11	2.90
230	1.90	2.27	2.15	2.96
240	1.93	2.31	2.19	3.01
250	1.97	2.35	2.23	3.06

considerable difference in emissive capacity under similar conditions of internal and external temperature.

The rate of emission is practically the same for hot water or steam, for equal differences in temperature.

The rate of emission is not affected by the internal volume of the radiator tubes, provided the sectional area is large enough to afford good internal circulation.

In still air, radiators having but one row of tubes are more effective than those having two or more rows.

With equal surfaces, in still air, low radiators are more effective than tall ones, and horizontal tubes are more effective than vertical ones.

86. Table 11 shows the actual emissive capacity of several varieties of *direct radiators* working in still air, as determined by experiment. The first column gives the difference in temperature, and the remaining columns, the total emission of heat per hour, in still air, per square foot of external surface, per degree difference in temperature.

TABLE 12.

FLUE RADIATORS—NATURAL DRAFT.

Surfaces.		Heat Emitted per Square Foot, per Hour, per Degree Difference.		Total Heat Emitted per Hour, per Degree Difference.	
Extended. Square Feet.	Square Feet. Plain.	Extended. B. T. U.	Plain. B. T. U.	Extended. B. T. U.	Plain. B. T. U.
A	B	C	D	E	F
57.80	40.40	1.65	1.97	95.37	79.58
6.40	4.24	2.05	2.39	13.12	10.13
63.10	41.20	1.39	1.85	87.81	76.22
7.18	4.50	1.90	2.24	13.64	10.08

87. The **comparative efficiency** of flue radiators and plain surface radiators of the same size may be seen in the experimental results shown in Table 12. The data in columns A, C, and E refer to the radiators in their original condition, having the usual ribs, etc., as shown in Fig. 25, while those in columns B, D, and F refer to the same radiators having all of the ribs and "extensions" removed.

It will be observed that, while the rate of emission from the plain surfaces is higher than that from the extended surfaces, yet the total emission is less. This result is due to the great difference in area of the actual emitting surfaces.

88. The average rate of emission of heat from ordinary *indirect radiators,* which are enclosed in a box and deliver warm air to rooms above through a vertical flue, is shown in Tables 13 and 14:

TABLE 13.

INDIRECT RADIATORS—NATURAL DRAFT, EXTENDED SURFACES.

Height of Flue. Feet.	Velocity of Air. Feet per Second.	Emission of Heat per Square Foot, per Hour, per Degree Difference. B. T. U.
5	2.90	1.70
10	4.10	2.00
15	5.00	2.22
20	5.70	2.38
25	6.30	2.52
30	6.70	2.60
35	7.14	2.67
40	7.50	2.72
45	7.90	2.76
50	8.20	2.80

89. The rate of emission of heat from radiators of the general style shown in Fig. 34, which are specially designed

for use with *forced blast* and are composed mainly of steel or wrought-iron pipe, is shown in the following table:

TABLE 14.

INDIRECT RADIATORS—PLAIN SURFACES, FORCED DRAFT.

TOTAL EMISSION OF HEAT PER SQUARE FOOT OF SURFACE, PER HOUR, PER DEGREE DIFFERENCE IN TEMPERATURE.

Velocity of Air. Feet per Second.	Heat Emitted. B. T. U.	Velocity of Air. Feet per Second.	Heat Emitted. B. T. U.
3	3.42	12	6.93
4	4.00	14	7.50
5	4.50	16	8.06
6	4.94	18	8.50
7	5.33	20	9.00
8	5.71	22	9.42
10	6.33	24	9.79

AMOUNT OF RADIATOR SURFACE REQUIRED.

90. The method of computing the amount of radiator surface required for any given surface, is as follows: Having ascertained the amount of heat to be supplied, in heat units per hour, the next thing to be done is to find the difference in temperature between the air to be heated and the heating fluid which is to be used in the radiators. If hot water is used, the temperature taken should be the average of its temperatures at entering and leaving the radiator. The coefficient of emission may then be found by referring to the preceding tables. The coefficient, or number which corresponds to the given difference of temperature, and to the kind of radiator which most nearly resembles the variety to be used, should be multiplied by the difference in temperature in degrees. The product will be equal to the total emission of heat per square foot, per hour, which may be expected. The area of radiator surface required may then be found by dividing the total amount of heat required per hour by the emission from 1 square foot as computed.

EXAMPLE.—A certain building requires a supply of heat amounting to 200,000 heat units per hour, and it is to be heated by steam having a temperature of 220°. The radiators are to be of the Detroit loop variety, 40 inches high, and are to heat by the direct system. How many square feet of radiator surface will be required to maintain the air in the building at 70°?

SOLUTION.—The difference in temperature between the heating agent and the air is 220° − 70° = 150°. The coefficient of emission for that difference of temperature is given in Table 11 as 1.63 for massed surfaces and 1.85 for a single row of tubes, 40 inches high. The efficiency of the radiator named will be somewhere between these, and the coefficient may be taken as 1.75. Then, the area of radiator surface required will be,

$$\frac{200{,}000}{150 \times 1.75} = 762 \text{ sq. ft.} \quad \text{Ans.}$$

91. For indirect heating, a greater amount of heat will be required. Of course, no fresh hot air can be introduced unless an equal amount of air be expelled from the room at the same time. Consequently, all of the heat contained in the fresh-air current below 70° (or the desired temperature of the room) will be lost by passing off with the spent air—that is, by ventilation. The fresh-air current must be heated from 20° to 50° hotter than the desired temperature of the room, so that, in cooling down to that temperature, it will give off an amount of heat sufficient to make good the loss by conduction through the walls, windows, etc.

Thus, in using a current of fresh air having a temperature of 110°, to maintain a room at 70°, the external temperature being zero, $\frac{70}{110}$ of the heat imparted to the current will be lost by ventilation, and only $\frac{40}{110}$ will be available to compensate for the loss of heat from the room through the windows and walls.

EXAMPLE.—The loss of heat from a certain building, by conduction through the walls and windows, is 200,000 B. T. U. per hour. It is desired to heat the building by the indirect system with natural draft, with steam having a temperature of 220°. The average temperature of the hot air on entering the rooms should be 40° above that in the rooms. The building is two stories high, and all the radiators should be located in the basement. How many square feet of radiator surface will be required to maintain the internal temperature of the building (neglecting the basement and attic) at a temperature of 70°, with the outer air at zero?

SOLUTION.—The losses of heat are as follows:

By conduction, $\frac{40}{110}$ of the total, or 200,000 B. T. U.
By ventilation, $\frac{70}{110}$ of the total, or 350,000 B. T. U.
The total loss per hour is 550,000 B. T. U.

The height of the flues we will say is about ten feet for the first story, and 20 to 25 feet for the second story; the coefficients of emission from the radiators will be $\frac{2+2.5}{2} = 2.25$ B. T. U. per hour. The difference between the temperatures of steam and the cold outer air is 220°. Then the required area is $\frac{550,000}{2.25 \times 220} = 1,111$ sq. ft. Ans.

92. Baldwin's Rule.—One of the most simple, and probably most correct, empirical rules used for computing the size of direct radiators is that originated by Mr. Wm. J. Baldwin; it is as follows:

Rule 7.—*Divide the difference in temperature between that at which the room is to be kept and the coldest outside atmosphere, by the difference between the temperature of the steam pipes and that at which you wish to keep the room, and the quotient will be the square feet or fraction thereof of plate or pipe surface to each square foot of glass, or its equivalent in wall surface.*

The quantity of heating surface found by this simple rule compensates only for the amount of heat lost by transmission through the windows, walls, and other cooling surfaces. It does not provide for cold air entering the room through loosely fitting doors, windows, etc., and an ample allowance must be made for this. Some buildings are so poorly constructed that 50 per cent. or more must be added to the amount of heating surface obtained by the above rule in order to counteract the cooling effect of these air leakages. A common practice is to add 25 per cent. for buildings of ordinary good construction. Besides this addition for air leakage, an ample allowance should be made for rooms exposed to cold winds, and this allowance should, if possible, be made in the form of an auxiliary radiator to prevent overheating the rooms during moderate weather.

93. As an example, suppose that we have three rooms *A*,

B, and *C*, as shown in Fig. 36, of precisely the same dimensions, and consequently having the same cubical contents, each room being 25 feet long by 20 feet wide, with a 10-foot ceiling. Let us also suppose that

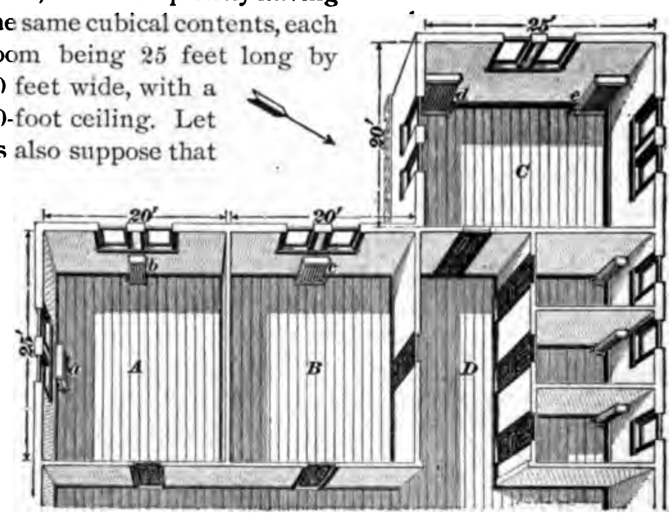


FIG. 36.

the halls, or corridors, *D*, and the other rooms in the building will be warmed to a temperature equal to that desired in *A*, *B*, and *C* by other radiators not shown. We are to find by the above rule the amount of heating surface required to maintain a temperature of 70° F. in *A*, *B*, and *C*, assuming that the radiators will be heated by steam having a pressure of 5 pounds by the gauge, when the outside temperature is 10° below zero. Let us suppose that the windows are each 6 ft. × 3 ft., and that the exposed walls are built of ordinary good brick, and that they are lathed and plastered inside.

Let S = amount of radiating surface required to counteract the cooling effect of the glass and its equivalent in *exposed* wall surface in square feet;

t = difference in degrees F. between the desired temperature of the room and that of the external air;

t_1 = difference in degrees F. between the temperature of the heating surface and that of the air in the room;

s = number of square feet of glass and its equivalent in exposed wall surface.

Then, applying Baldwin's rule,

$$S = \frac{t}{t_1}s.$$

When lathed-and-plastered brick walls are used, as in the figure, it is safe to estimate that about 10 square feet of wall surface will be equivalent in cooling power to 1 square foot of glass; consequently, in this case,

$$\frac{\text{wall surface}}{10} = \text{equivalent glass surface.}$$

Let us commence with the room A; the amount of glass surface here is $6 \times 3 \times 4 = 72$ square feet. To this must be added the exposed wall surface reduced to a glass equivalent; thus,

$$\frac{10\,(25 + 20) - 72}{10} = 37.8 \text{ sq. ft.}$$

Since we assume that the inner walls, floors, and ceilings are not cooling surfaces, then the only cooling surfaces we have to allow for in the case of A is $72 + 37.8 = 109.8$ square feet $= s$.

By substituting in the formula, we have, since the temperature of steam at 5 pounds gauge pressure is 227°, and the difference between 70° above zero and 10° below zero is $70° + 10°$,

$$S = \frac{70 + 10}{227 - 70} \times 109.8 = 56 \text{ sq. ft., nearly.}$$

This, however, only counteracts the cooling effect of the walls and windows, and to make reasonable allowance for air leakage, we will add 25 per cent., or 14 square feet, which gives us $56 + 14 = 70$ square feet of direct radiating surface. Now, suppose that we allow 20 per cent. of the direct radiating surface (70 square feet in this case) for a moderate exposure to winds; the amount of heating surface, that is, the radiator which we would place in A, will have an area of $70 + 14$, or 84 square feet.

For convenience, we may divide this into two radiators, *a* having an area of 56 square feet, and *b* an area of 28 square feet. This will so divide the radiator surface that one-third, or 28 square feet, may be used for duty during mild weather; two-thirds, or 56 square feet, for moderate cold weather; and the whole, or 84 square feet, for use during severe weather.

In like manner and under the same conditions, we find that the sizes of the radiators *c*, *d*, and *e* should be, respectively, 40, 82, and 42 square feet.

As the coldest winds blow in the direction of the arrow, we place the 82-square-foot radiator in the left-hand exposed corner of the room *C*. A better distribution of the radiator surface in this room would be to make *d* 42 square feet only, and place a radiator having 40 square feet between the windows towards which the arrow points; this will give a more uniform temperature to the room.

94. It will be observed that *A*, *B*, and *C*, which are three rooms having the same shape and cubical contents, respectively require 84 square feet, 40 square feet, and 124 square feet of heating surface, in order to maintain a temperature of 70° F. in each while the outer atmosphere is 10° below zero. This shows how imperfect must be the rule-of-thumb method of proportioning radiators to the cubical contents of the several rooms.

For direct-indirect heating, the area of radiator surface required may be found by computing the area required for direct heating, and adding 25 per cent. to that amount. Thus, in the example in Art. **90**, if the heating be done by the direct-indirect method instead of the direct method, the radiator surface required would be $762 + 190.5 = 952.5$ square feet.

LOSS OF HEAT FROM BUILDINGS.

95. Heat escapes from buildings in two ways: *first*, by conduction through the windows, walls, floor, and roof, and *second*, by ventilation or leakage of warm air. The loss from the latter cause will depend upon the tightness of the windows and doors and upon the thoroughness of the construction

of the walls, especially in wooden buildings. If the outer walls are exposed to the wind, the loss of heat by conduction will be increased from 10 to 30 per cent., while, if they are not wind-tight, the loss by escape of air will be increased to an unknown amount.

96. The rate at which heat will be lost through walls and windows has been found, by careful experiment, to be proportional to the amount of the difference in temperature between the inside and the outside air. The rate of loss under ordinary conditions, and in rooms which have only a moderate exposure to wind, is shown in the following table; the loss is given in B. T. U. per hour, per square foot of heating surface for 1 degree rise in temperature:

TABLE 15.

LOSS OF HEAT.

Character of Surface.	B. T. U. per Hour.
Window, single glass	.776
Window, double glass	.518
Skylight, single glass	1.118
Skylight, double glass	.621
Brick wall, 4 inches	.680
Brick wall, 8 inches	.460
Brick wall, 12 inches	.320
Brick wall, 16 inches	.260
Brick wall, 20 inches	.230
Outer doors	.420
Floors, wooden beams, planked	.083
Floors, fireproof, floored with wood	.124
Ceilings, wooden beams, planked	.104
Ceilings, fireproof construction	.145
Ordinary wooden walls, lathed and plastered, sheathing 1 inch thick on studding, covered with building paper, weather-boarded	about .100

The thickness of the window glass matters very little. The *double* glass referred to means two sheets of glass with an air space between them.

If brick walls be made double, with an air space in the middle, the air space will reduce the loss of heat below that of a solid wall having an equal thickness of brick. The saving will be about .07 or .08 heat unit per square foot.

97. The losses shown in the table will be increased by circumstances about as follows: where the exposure is northerly, and the winds are strong, 10 per cent.; when the building is heated during the day, and is allowed to cool off partially during the night, the exposure being moderate, 10 per cent.; same, northerly exposure with high winds, 30 per cent.; when the building is heated only a day at a time, and is allowed to freeze for intervals of several days, such as churches and audience rooms, 50 per cent.

The temperature of cellars that are not warmed may be assumed for purposes of calculation to be 32°. Vestibules and corridors which are frequently opened to the outer air, and which are not heated, may be assumed to have a temperature of 20°.

98. In computing the loss of heat from the air within a room, all of the surfaces must be considered, the ceiling and floor as well as the ends and sides. If a room is located over a cold cellar or a cold corridor, the cooling effect of the floor must be considered. If a room is covered with a flat roof and is ceiled, or lathed and plastered on the rafters, the cooling effect of the ceiling may equal or even exceed that of the walls. If there is a space between the roof and the ceiling which is not wind-tight, the temperature of the ceiling should be assumed to be 10°.

In computing the total loss of heat from a building which is to be warmed throughout, the interior walls, floors, and ceilings may be disregarded, and only the outer walls, windows, doors, roof, and first floor should be considered.

99. In many instances the loss of heat from the room will be partially compensated for by the heat which is emitted

from gas lights, and by persons occupying the room. The amount of heat from these sources is about as follows:

	B. T. U.
Each adult person...........................	400
Ordinary 5-foot gas burner, 15 candlepower.....	4,800
Welsbach incandescent lamp, 50 candlepower...	2,000
Electric incandescent lamp, 16 candlepower	220

In lecture halls and large audience rooms, the amount of heat given off by the audience and the lights may equal or exceed that which is lost through the walls and windows. When this occurs, it becomes necessary to lower the temperature of the fresh-air supply. It may even require to be reduced below the desired temperature of the room, during the presence of the audience. Thus, the actual amount of heat required in any certain case may vary from hour to hour, although the atmospheric temperature is stationary.

The heating apparatus, however, must be capable of maintaining the temperature of the rooms at the desired degree without the aid of the lights and when no audience is present.

The total amount of heat to be supplied by the apparatus should, therefore, be taken as fully equal to the loss by ventilation plus the loss by conduction through the walls and windows or other cooling surfaces.

VOLUME AND TEMPERATURE OF HOT-AIR SUPPLY.

100. The loss of heat per hour by conduction through windows, walls, etc. being given, and also the *temperature* of the hot-air supply and the desired temperature of the room, the required volume per hour may be computed by the following rule:

Rule 8.—*Multiply the amount of heat lost by conduction per hour, in heat units, by 58; divide the result by the difference, in degrees, between the given temperatures of the room and the hot-air current. The quotient will be the required volume of hot air, in cubic feet per hour.*

EXAMPLE.—The loss of heat by conduction from a certain building is 200,000 heat units per hour; the temperature of the fresh hot air may be taken as 110°, and the rooms are to be maintained at 70°. What should be the volume of the hot-air supply?

SOLUTION.— $\frac{200,000 \times 58}{110 - 70} = 290,000$ cu. ft. per hr. Ans.

101. The volume of hot-air supply is generally determined by the requirements of ventilation, and its temperature is made just sufficient to afford the amount of heat required.

The desired volume of the fresh-air supply in cubic feet per hour, the amount of heat lost by conduction, in heat units per hour, and the desired temperature of the rooms being given, the following rule may be used to compute the temperature which the hot air should have on entering the rooms:

Rule 9.—*Multiply the amount of heat lost by conduction, in heat units per hour, by 58, and divide the result by the given volume of the air-current. Add the quotient to the desired temperature of the room; the sum will be the required temperature of the hot-air supply.*

EXAMPLE.—A certain building requires 480,000 cubic feet of air per hour for heating and ventilation. The amount of heat lost from the rooms by conduction is 200,000 heat units per hour, and the rooms must be maintained at a temperature of 70°; what must be the temperature of the fresh-air supply at entering the room?

SOLUTION.— $\frac{200,000 \times 58}{480,000} + 70 = 94.17°$. Ans.

PREVENTING LOSS OF HEAT.

102. No material is known which will totally obstruct the passage of heat by conduction. There is, however, a great difference in the conductivity of materials, and those which conduct heat very slowly are called by the general name of **non-conductors.**

In a general way, the efficiency of non-conducting materials is proportional to their lightness per cubic foot.

Thus, heat passes through a solid plate of glass with comparative freedom, but a layer of "mineral wool" or "slag wool" (which is merely glass blown into fine threads) of the same weight per square foot of surface, exhibits very much less conducting power.

The materials used as non-conductors vary greatly in durability, and this fact should be carefully considered when estimating the saving that may be accomplished by using them.

All non-conducting coverings should be well protected against displacement, or the entrance of either air or moisture. A covering of painted canvas, well secured by copper wire, is usually sufficient for pipes which are not exposed to the weather, but in all exposed places great care should be taken to make the outer casings perfectly waterproof.

TABLE 16.

NON-CONDUCTING COVERINGS.

Kind of Covering.	B. T. U. Transmitted per Hour per Square Foot of Surface, per Degree Difference of Temperature.	Loss Per Cent.
"Manville" sectional and hair felt.	0.2169	8.00
Rock wool	0.2556	9.50
Mineral wool	0.2846	10.50
"Champion" mineral wool	0.3166	11.72
"Manville" wool cement	0.3448	12.77
"Manville" sectional	0.3496	12.94
Magnesia	0.3838	14.20
Hair felt	0.4220	15.62
Fire felt	0.5023	18.60
Fossil meal	0.8787	32.54
"Riley" cement	0.9531	35.30
Bare pipe	2.7059	100.00

The differences in the efficiencies of the various non-conductors now on the market are much less than usually stated in advertising literature.

HOUSE HEATING.

SYSTEMS OF HEATING.

103. The methods of house heating now in vogue may be divided into two classes, called **direct** and **indirect.** The distinction between them consists solely in the mode of supplying the heat. In the direct method, the heat is emitted from stoves or radiators contained within the room to be warmed; in the indirect method, the heat is supplied by a current of hot air which is brought in from some outside source.

Several modifications and combinations of these methods are also used. The so called **direct-indirect** method is one in which the room is warmed by the direct action of a radiator or heater, and, in addition, a current of fresh air is allowed to enter the room from the outer atmosphere. This fresh air, however, is compelled to pass through the heater and become warmed before it mingles with the air in the room. The direct-indirect system is a combination of a system of direct heating with one of direct ventilation, the ventilation usually being limited to the room containing the heater. If there is no vent by which air may flow out of the room at the same time that the fresh air flows in, the current cannot be maintained, and the heater then operates like any direct heater.

Indirect-heating systems are usually combined with a system of ventilation, but are sometimes operated without it. Indirect heating is sometimes practised by means of a heater, or *stack*, which takes cold air from a room, and, after warming it, returns it to the same room through the ordinary hot-air flues and registers. This method is highly objectionable from a sanitary point of view, but it is sometimes used for warming hallways or large rooms which

contain only a very few people. The air within a room may be heated and kept warm, without introducing any fresh air, by either the direct or indirect method. Thus, it will be seen that ventilation is not inseparably connected with either system of heating.

The direct-heating system is usually operated without any provision for ventilation, and it is not suitable, therefore, for warming dwellings or rooms which are occupied by people.

104. General Requirements of a Heating System. In order to heat and ventilate a room in a satisfactory manner, it is necessary to secure the following desiderata:

1. A uniform distribution of heat throughout all parts of the room, as far as possible.
2. A thorough diffusion of fresh air throughout the level or zone in which persons breathe.
3. A prompt and complete removal of all foul air from the room.
4. A means of preventing all waste of heat, caused by the premature escape of the heated air.
5. A means of avoiding perceptible currents or drafts of either warm or cold air.

LOCATION OF INLETS AND OUTLETS.

105. The **circulation of air,** and consequent distribution of heat throughout a room, depends greatly upon the locations of the air inlet and outlet, and upon the location of the radiator or stove relatively to the cold exterior walls.

The circulation which is caused by the introduction of warm air and the expulsion of foul air, at various points, is shown in Figs. 37 and 38. Fig. 37 shows the interior circulation in a room which is heated in the ordinary old-fashioned way. The hot air enters at *a* and escapes through a ventilating register *b*, which is located near the top of the wall at

the opposite end of the room. The direction of the currents is shown by the arrows. The air composing the main current *c* is much warmer than that in the space *d*. There will

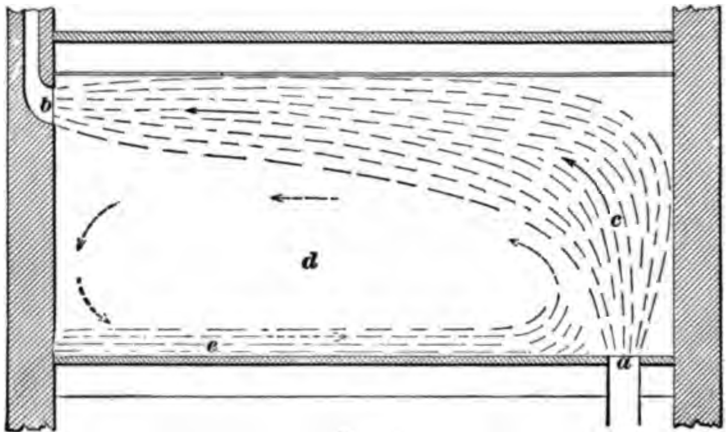


FIG. 37.

be some circulation in this space, as shown by the dotted arrows, but it is usually very sluggish. There will usually

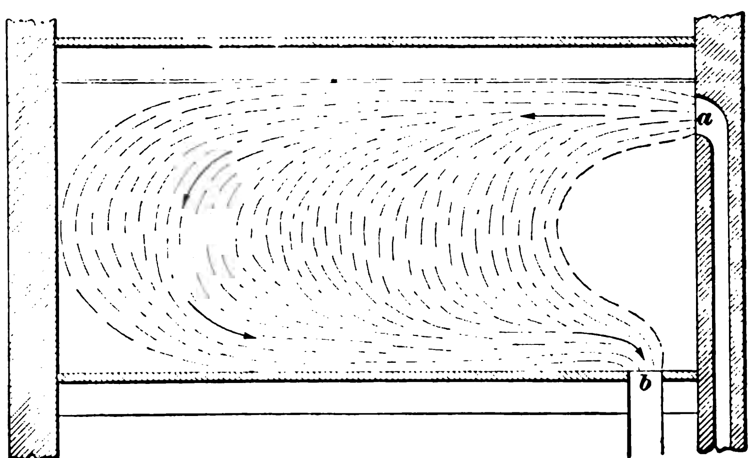


FIG. 38.

be a layer of cold air, more or less foul, near the floor at *e*. The current of fresh hot air passes through the room so

directly and quickly that it will not diffuse into the main body of air at *d*, to a sufficient extent to freshen it properly. There will be a considerable difference in temperature of the air at the floor and at the breathing level, and the inmates of the room are likely to suffer more or less discomfort in consequence. The hot air escapes from the room at a high temperature, and a large percentage of the available heat is thereby wasted.

If the outlet in Fig. 37 is brought down near the floor, the inlet remaining in the same position, the premature escape of the hot air is prevented and the distribution of heat is somewhat improved, but it is still quite imperfect.

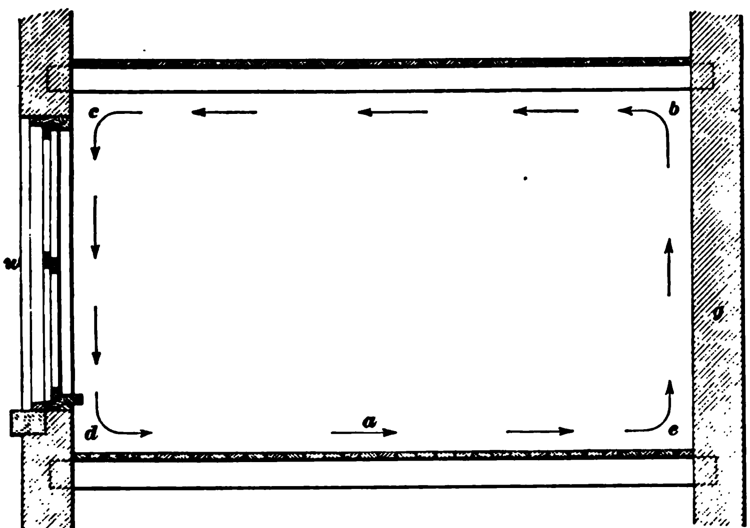


FIG. 39.

In Fig. 38 the location of the outlet is changed by placing it at or near that end of the room at which the fresh air enters. The fresh-air current passes forward towards the opposite wall, spreading out and moving more slowly as it proceeds, and it gradually settles downwards and returns along the floor to the outlet *b*.

The fresh air is thus induced to travel the length of the room *twice*, instead of once, as in Fig. 37, and, if the

arrangements are not at fault otherwise, the distribution of heat and the freshening of the apartment will be very satisfactory.

106. The general circulation within a room will be greatly influenced by the nature and extent of the cooling surfaces, such as windows and exterior walls. If there is a large window in the room the air will tend to circulate as shown in Fig. 39. Being rapidly cooled by contact with the glass, it will flow downwards with considerable velocity, and the current will spread out upon the floor, thus forming a cold stratum at *a*. The upward currents of air in other parts of the room, to compensate for the downward current, will be so diffused and slow as to be imperceptible.

A radiator placed at *a* would prevent cold air from falling to the floor, and would tend to equalize the temperature of the room.

107. In general, the supply of hot air should be brought into the room at a level above the heads of the inmates, and not up through the floor. The object is not only to secure proper circulation, but to prevent the incoming current of hot air from impinging upon people in the room and thus becoming a source of discomfort. The minimum height for hot-air inlets is found in practice to be about 8 feet above the floor, in rooms of moderate dimensions and with currents of low velocity.

In large rooms having high ceilings, the inlets should be placed at a greater elevation, generally not less than two-thirds the height of the ceiling. In large audience rooms it is advisable to introduce the hot air at a low velocity through openings in the ceiling, and to take out the spent air through openings in or near the floor.

The number of hot-air inlets which will be required will depend upon the dimensions of the room. The air must be introduced at a sufficient number of points to secure a thorough distribution of the heat throughout the room. One inlet is usually sufficient for the rooms commonly found

in dwellings and offices, but, in large parlors, music rooms, etc., two or even more may be employed to good advantage.

Hot air should not be introduced through **floor inlets,** except in hallways and anterooms, for the purpose of warming persons who have been exposed to the cold.

108. **Floor outlets** for foul air should be arranged to avoid a draft in the vicinity of the outlet. If only a single outlet is provided, having about the same area as the inlet, the current near its orifice will have nearly the same velocity as the hot air coming from the inlet, and it will cause a draft at that point. It is, therefore, necessary that the outgoing currents be divided, by increasing the number or area of the outlets sufficiently to avoid drafts of objectionable velocity.

In the case of audience rooms, the outlets should be made in the form of long, narrow slits extending horizontally at the base of the walls, or around the edges of platforms. If the floor is stepped, the outlets may be made in the risers.

The plan of taking the foul air out through a large grating in the floor in the center of a hall, is not a good one.

LOCATION OF RADIATORS AND REGISTERS.

109. It is common practice to place radiators, hot-air registers, and stoves near the inner end or corner of a room. This proceeding is wrong in principle; the only advantage that can be gained by such an arrangement is that the heating apparatus is thereby concentrated near the center of the building, and consequently the amount of horizontal piping required is less than it would be if they were placed near the outer walls. A small economy in first cost is thus secured, but the efficiency of the apparatus is sacrificed.

The main objection to placing hot-air registers and ducts in the outer walls of a building is that the hot air is likely to be chilled and thus the circulation impaired. This may be prevented, however, by providing the duct with a proper

covering of non-conducting material upon the outer side. The heat which escapes from the inner side passes into the room and does useful work.

Direct radiators should always be located near the outer walls, or where the cooling influence is greatest.

Direct-indirect radiators are necessarily placed against the outer walls, and therefore are usually located properly.

Indirect radiators should always be located at a sufficient distance below the hot-air register to cause the air to pass through them at a proper velocity.

In factories and workshops, pipe coils are often placed overhead, suspended horizontally at a distance of not less than 4 feet above the heads of the workmen, and not less than 1 foot below the ceiling. The machinery, and the belting which drives it, will carry the heated air downwards towards the floor, and will usually diffuse it throughout the apartment in a satisfactory manner. Overhead heating, however, is not satisfactory when the air is not in perceptible motion.

HOT-AIR FLUES AND REGISTERS.

110. The carrying capacity of a flue or duct is controlled by the temperature of the hot air and the height of the flue, in the same manner as a chimney. A flue which extends to the third story of a building will discharge more air per minute than a similar flue which discharges at the second or the first floor. This is because the column of hot air extending to the third floor is higher than the others, and consequently the upward pressure is greater. In Table 17, which gives the velocity of air in flues, in feet per minute under natural draft, an allowance of 50 per cent. over the theoretical flow has been made for friction and other common resistances. This will be sufficient for all ordinary circumstances. It should be borne in mind that the volume of flow shown in the table cannot be attained unless the air in the room is permitted to escape freely and as rapidly as the fresh warm air is inclined to come in.

TABLE 17.

Difference in Temperature Degrees F.	Height of Flue in Feet.								
	10	15	20	30	40	50	60	80	100
10	108	133	153	188	217	242	264	306	342
15	133	162	188	230	265	297	325	375	420
20	153	188	217	265	306	342	373	435	485
25	171	210	242	297	342	383	420	485	530
30	188	230	265	325	375	419	461	530	594
40	216	265	305	374	431	482	529	608	680
50	242	297	342	419	484	541	594	680	768
60	266	327	376	460	532	595	650	747	842
70	288	354	407	498	576	644	703	809	910
80	308	379	435	533	616	688	751	866	972
90	326	401	460	565	652	728	795	918	1029
100	342	419	484	593	684	765	835	965	1080
125	384	470	541	664	766	857	939	1085	1216
150	419	514	593	726	838	937	1028	1185	1325

The difference in temperature given in the table is that existing between the outer atmosphere and the average of the air in the flue.

Each register should be supplied by an independent vertical duct.

REGULATION OF TEMPERATURE.

111. The method which may be used for controlling the temperature of the air within a building depends upon the system of heating which is employed, and also upon the heating agent, whether steam, hot water, or hot air. The emission of heat from a *steam* radiator may be graduated in several ways:

1. By dividing the radiator into several independent sections and admitting steam to more or fewer of them, as desired.

2. By admitting steam at full pressure and shutting it off again at moderate intervals, in regular alternation; the *average* temperature of the radiator thus obtained depends upon the relative length and frequency of the intervals.

3. By varying the pressure of the steam.

The first method is a good one and is used to some extent, but its general use is prevented by the lack of suitable apparatus. The expense and bother of adapting the varieties of radiators now on the market, and making the necessary connections, with valves of the ordinary kind, is almost prohibitory.

The second method is usually operated by means of automatic valves, which are similar in general principle to pressure-reducing valves.

The third method is commonly applied by varying the intensity of the fire under the boiler, or by the use of an automatic pressure-reducing valve, the adjustment being varied to give the desired steam pressure.

The emission of heat from a *hot-water* radiator may be graduated by adjusting the inlet valve, thus controlling the amount of hot water which flows through it.

When the *indirect-heating* system is employed, the temperature of the air which is delivered by the apparatus may be controlled, not only by modifying the emission of heat from the radiators, but by mixing the hot air with a sufficient quantity of cold air to obtain the temperature desired. The former method is so slow in operation that it is not generally satisfactory; but the latter method produces the desired result very promptly and is easy to manage.

When hot-air *furnaces* are used for heating, the methods of controlling the temperature by mixing, or by operating the registers, are the only ones which will give satisfaction. Regulation by varying the fire, even although it is most commonly done, is altogether too slow and uncertain.

112. Mixing Valves.—Fig. 40 shows the mode of applying a **mixing valve** to a duct leading from the mains of an ordinary forced-blast system. Hot air flows through the duct *a*, and cold air is supplied by the duct *b*. The

opening of *b* into *a* is covered by a valve *v*, which is hinged as shown. By moving the valve up or down, the proportions of hot and cold air which pass into the flue *f* may be varied as desired. As the opening for cold air is increased, the flow of hot air is restricted, and vice versa, but the valve does not operate to increase or diminish the volume of the current passing up the flue *f*.

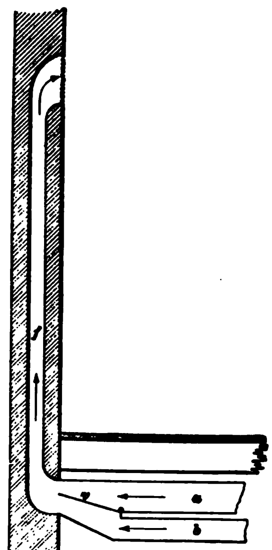


FIG. 40.

Fig. 41 shows the application of a mixing valve to an indirect radiator. The radiator is enclosed in the case *a*, and is supplied with fresh cold air by the duct *b*. Warm air is delivered through *d* into the flue. The duct *b* is connected to *d* by a by-pass pipe *c*, and the opening is controlled by a valve *v*, which is hinged as shown. This valve permits more or less cold air to pass directly into the flue without passing over the radiator. The flow of air through the radiator box *a* is checked to the extent that air is allowed to pass up the pipe *c*. The area of the opening of the valve *v* usually does not require to be more than one-third to one-half that of the vertical duct.

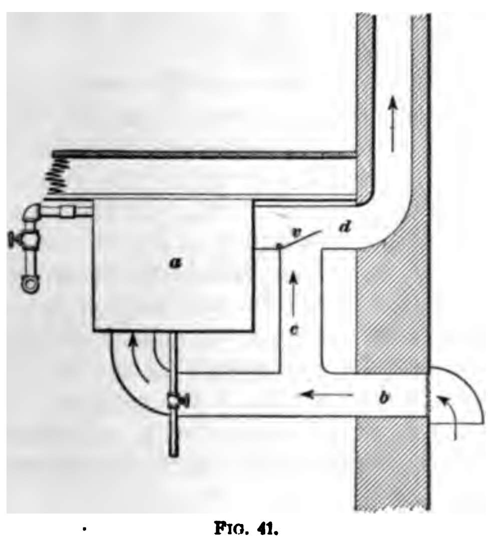


FIG. 41.

The mixing valve should be located at the foot of the vertical duct, and it may be operated from any floor by means of suitable connections of wire and chain. If desired, the connections may pass down through the flue.

All mixing valves should operate to change the *proportions* of the hot and cold air, without affecting the volume of the currents passing into the rooms.

113. Automatic Temperature Regulators.—Regulators that are commonly used to automatically control the operations of a heating apparatus are arranged either to operate the furnace dampers and thus control the fire, or to vary the adjustment of a mixing valve, or to open and close or regulate the apertures of valves which govern the flow of the heating fluids.

There is a class of *damper regulators* which are operated by the pressure of the steam in the boiler, but they are useful only for regulating combustion of the fuel and so maintaining a constant pressure of steam.

There is another class of regulating apparatus which is operated by the heat of the air in the room that is to be warmed. These are called **thermostats.**

The internal construction of a thermostat which operates by the expansion of a volatile liquid is shown in Fig. 42. It consists of a metal shell which is divided into two chambers *a* and *b* by the flexible corrugated diaphragm shown. The chamber *b* is partly filled with the liquid, as shown. The pressure of the vapor above the liquid is always proportional to the temperature. Naphtha is an excellent material for this purpose, because the pressure of the vapor at temperatures of 70° or 80° amounts to several pounds per square inch, and thus furnishes sufficient force to operate ordinary dampers, etc.

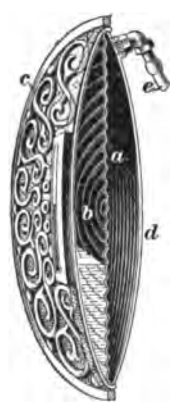


FIG. 42.

When the temperature of the air around the thermostat increases, the vapor pressure

rises correspondingly and forces the diaphragm towards the chamber *a*. The movement of the diaphragm may be utilized in any convenient manner to operate valves, etc. If the valve or damper moves easily it may be operated by means of a diaphragm motor, the tube *c*, which connects the thermostat to the motor, being filled with water. The motion of the thermostat diaphragm will thus be transmitted to the motor diaphragm and to a lever, which will increase it sufficiently to operate an ordinary damper.

There are also many other devices—electrical, pneumatic, etc.—for the same general purpose, having various degrees of merit.

Thermostats when in use are usually covered with an ornamental grille, and are attached to the side walls of the room. Care must be taken in locating them to secure a position where the temperature will be the average temperature of the room, or nearly so. Therefore, the vicinity of hot-air inlets or foul-air outlets should be avoided.

METHODS OF MOVING AIR.

114. The movement of air which is required for the purpose of heating and ventilation may be accomplished by means of **natural draft** or by **forced draft.**

In both systems the power employed to move the air is derived from heat. In the former system it is applied to the air directly to expand the air and reduce its weight, so that the colder and heavier atmosphere will displace the warmer air and drive it through the flues, as desired. In the latter system the heat is first converted into mechanical power through the agency of a boiler and engine, and is then applied to moving the air by means of a fan. Of course, the conversion of heat into power is attended with considerable loss; but, after making all proper allowances for imperfections of machinery, etc., it is found that, in order to move a given quantity of air, the former system requires about one thousand times as much heat as the latter.

The mechanical apparatus usually employed for moving air in large quantities, at the low pressure required for heating and ventilation, consists chiefly of ***steam-jet blowers*** **and** ***fans.***

FANS.

115. The general construction of a centrifugal fan is shown in Figs. 43 and 44. It consists of a wheel *a*, which revolves swiftly within a circular casing *c*, which has a number of internal vanes, or blades *b*, *b'*. Air enters the casing at the central opening *d* and is expelled through the nozzle *e*.

The only effect that can be produced by a fan is a greater pressure of air at the outlet than at the inlet. In conse-

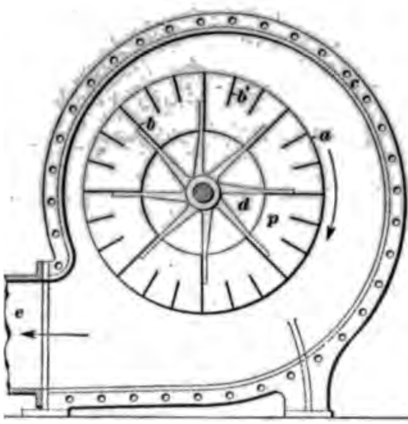


FIG. 43.

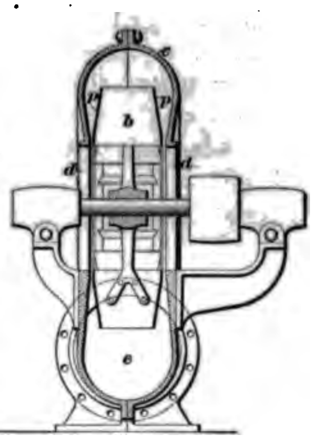


FIG. 44.

quence of the partial removal of the air from the central to the outer part of the fan, the pressure of the air at the center diminishes accordingly. If the inlet be open, the atmosphere will rush in and restore the pressure to the normal.

The distinction commonly made between **exhaust fans** and **pressure fans** depends wholly upon the manner in which they are employed. When the air duct is connected to the inlet of the fan, the pressure of the air which passes through it will always be below that of the atmosphere. The fan is then called an *exhaust* fan. On the contrary,

when the air is forced through a duct which is attached to the outlet of the fan, the pressure of the air will always be above that of the atmosphere, and the fan is then called a *pressure* fan.

The construction of the fan is substantially the same in both cases, and the mode of operation is always the same.

116. The *pressure of the blast* depends chiefly upon the velocity of the wheel, measured at the rim.

The *volume of the blast* depends upon the amount of air that can be induced to flow into the wheel through the inlet.

The *size of the inlet opening* must be proportioned to suit the volume and velocity of the inflowing air; it bears no relation to the diameter of the wheel.

The *diameter of the wheel* should always be made large enough to secure the desired velocity at the rim with a moderate rotative speed. There is much less waste of power due to the eddying of the air between the blades in a large wheel than in a small one. Therefore, a given volume and pressure of blast may be produced much more economically by a large wheel rotating at a moderate speed than by a small wheel rotating at a higher speed. The small wheel must rotate faster to secure the same velocity of rim and thus generate the required pressure.

The wear and tear on belting, countershafts, and bearings will be greatest with the small wheel. The small wheel will also make more noise than a large one doing the same work.

The *power* required to drive a fan, in addition to that consumed in friction and internal waste, will be equal to the volume of air delivered from the nozzle, in cubic feet per minute, multiplied by the difference between the pressures at the inlet and the delivery in pounds per square foot.

For all moderate or low pressures, the blades of the wheel should be radial, and their length should not exceed one-fourth of the diameter of the wheel, and they may in many instances be made much shorter. The sides of the wheel should be enclosed, as shown, to prevent the air from

escaping past the edges of the blades and thus forming useless eddies. The side plates *p* may be made somewhat conical, mainly for the purpose of stiffening the wheel. The casing should afford plenty of space into which the air may escape from the rim of the wheel, and it should not approach the sides of the wheel too closely, except at the rim of the inlet opening. The area of the cross-section at any point should not exceed the area of the discharge nozzle.

The outlet nozzle may be directed horizontally or at any desired angle, and care should always be taken in purchasing fans to have the outlet turned in a proper direction, so as to avoid all unnecessary turns or elbows in the connections.

The outlet nozzle should always extend at a tangent to the case, and should never extend radially.

When small fans are driven by horizontal belting, they should be mounted on a sliding bed so that the belts may be tightened by shifting the fan slightly.

Two fans should not deliver into the same conduit, unless one is to be used only as a reserve for the other. If the system is too large for one fan, it should be divided into smaller but independent systems.

Of course, two or more fans of equal power may be *coupled*, if they are driven by the same countershaft, or are otherwise provided with means for maintaining an equality of speed and pressure.

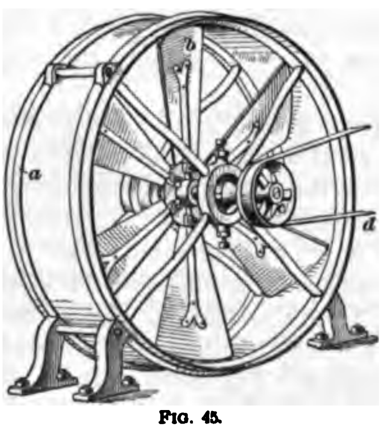


FIG. 45.

117. The propelling wheel, or **disk fan,** Fig. 45, is composed of a number of vanes *b*, which are attached to a shaft *c* and are set at an angle to the shaft as shown. They are rotated rapidly within the casing *a*; and while

they whirl the passing air, the centrifugal force thus generated is largely wasted and the principal effect is exerted by the inclined faces of the vanes which press the air forwards.

This variety of fan applies power to very poor advantage, and is the most wasteful and inefficient form in use. It should never be employed for moving the main air-current in heating or ventilating operations.

STEAM HEATING.

STEAM GENERATORS.

REQUIREMENTS OF STEAM BOILERS.

118. The process of making steam consists in transforming water from the liquid to the gaseous condition. This can be accomplished only by the application of heat. In order to perform this work efficiently and rapidly, it is necessary that boilers should have good **internal circulation,** so that the water may be brought into actual contact with the heating surfaces to the greatest practicable extent.

In order to secure a high degree of efficiency, it is necessary that the parts of a boiler be so arranged that the mingled steam and water may flow upwards and away from the heating surfaces with entire freedom, and that the water, after parting with the steam bubbles, may flow back to the heating surfaces by a route which will avoid all interference with the ascending currents. If the flow of the ascending currents is impeded or obstructed by reason of insufficient passageways, so that the steam cannot freely escape from the water, there is danger of the water being lifted up or forced out of contact with the heating surfaces. This state of affairs may last from a few seconds to many minutes, according to the misconstruction of the boiler. Boilers must

be made of material which will *transmit* heat readily, and the parts must be so arranged as to *absorb* the maximum amount of heat from the hot gases passing over them. It is important, also, that the parts be so arranged that they can easily be kept clean and in good condition for the transmission of heat.

They must be designed in a manner that will insure safety, not only under the strain of ordinary regular work, but when neglected, and when worn by long service. The greatest danger to contend with, in many cases, is ignorance of persons in charge of the boilers.

119. Direction of Flow of Gases.—The efficiency of a boiler tube is considerably affected by the manner in which the hot gases pass over its surface. If they flow in a direction parallel with its length, much less heat will be transmitted through it than if they impinge upon it at right angles or flow crossways over it. The latter condition can be secured only in those boilers which have the water inside of the tubes.

The movements of the water and of the hot gases should be in opposite directions, as nearly as practicable, in order that the coolest part of the water may be exposed to the coolest gases, and that, as its temperature rises, it may be acted upon by successively hotter gases. The greatest practicable temperature difference is thus maintained throughout the whole passage of the gases through the boiler, and consequently the maximum amount of heat will be transmitted to the water. If the reverse arrangement were employed, the temperature difference would be greater near the fire than it would be elsewhere in the flues, and the total transmission of heat would be considerably less. The aim should be to have the temperature of the gases at the moment they leave the tubes as near to the temperature of the steam as possible, but not to exceed it by more than 100 degrees.

The length of a boiler tube which contains water, as in water-tube boilers, is limited by the rapidity and abundance of the circulation. Very long or very slender tubes are

generally objectionable, because of the difficulty of keeping them properly filled with water.

120. Stayed Surfaces.—Internal steam pressure tends to distort the shape of any vessel which is not truly *spherical* or *cylindrical* in form, and the tendency is proportional to the extent of the variation of its shape from those forms.

All surfaces, curved or flat, which are exposed to steam pressure must be stayed or braced, whenever the shape is such that the internal space of the boiler might be increased by bulging or otherwise distorting them.

Flat surfaces are more liable to distortion by steam pressure than any others, and they must be carefully supported by *stays* or braces. These must be attached to the plates at short distances apart, the proper distance depending upon the thickness of the plate and the maximum pressure to be carried in the boiler.

Stayed surfaces should be avoided whenever practicable, because the bolts and rods are liable to become weakened by corrosion, and it is impossible in many cases to inspect them.

121. Tubes, Manholes, Etc.—All boiler tubes of steel or wrought iron should be secured in place by the process called *expanding*, and not by threaded screw joints. Screw joints should not be permitted in any form of boiler where they will be exposed to the action of hot gases or fire.

All varieties of boilers should have ample facilities for internal inspection and cleaning. All chambers large enough to admit a man should be provided with **manholes**, and other parts should have **handholes** located at such points that the condition of the plates and stays can be readily seen.

DESCRIPTION OF BOILERS.

122. Boilers containing tubes are divided into two chief classes. Those which have the hot gases passing through the tubes are called **fire-tube boilers**, while those which

have water upon the inside of the tubes and hot gases upon the outside, are called water-tube boilers.

123. **The return-tubular boiler** is shown in Figs. 46

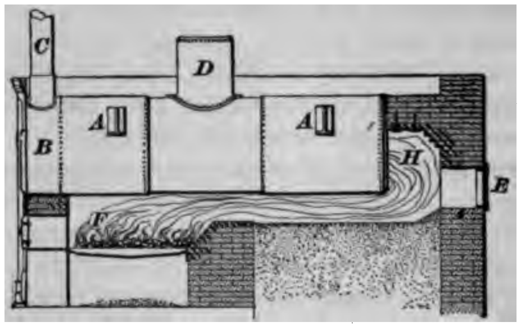


FIG. 46.

and 47. It is so called because the hot gases pass along under the shell of the boiler and *return* through the tubes to the smokebox *B*; the gases then flow into the smokestack *C*. The boiler is supported upon the side walls by means of angle brackets *A*. These should carry the entire weight of the boiler. The tubes can be got at for cleaning by opening a door in front of *B*, and the soot and ashes can be scraped out through the door *E*. The boiler is usually provided with a dome *D*, though this is sometimes left off. Return-tubular boilers are often used for generating steam for heating and power purposes for large buildings.

FIG. 47.

124. In the **locomotive boiler** the firebox is internal, and is substantially rectangular in form. The hot gases are conveyed to the smokebox, in a direct course, by the tubes, which are small in diameter and as numerous as possible, so as to secure a large amount of heating surface. The largest part of the total evaporation, however, takes place upon the

sides and top of the firebox. These boilers are commonly used for factories, mills, etc.

125. Fig. 48 shows a **vertical tubular boiler** designed for low pressure and small work. The tubes are short, and the firebox is very large in proportion to the size of the shell. The hot gases, after passing through the tubes, are passed downwards over the outer surface of the shell, and are allowed to escape through an outlet Q near the bottom. The jacket S consists of a metal shell, which is lined with non-conducting and refractory material. An inclined partition P extends around the boiler to the point X, and compels the gases to pass over nearly the whole outer surface of the boiler shell. The heating surface is thus considerably increased.

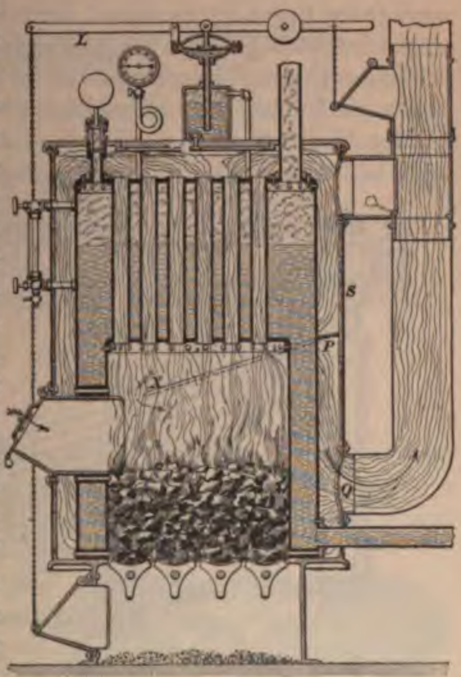


FIG. 48.

126. A **water-tube boiler** is shown in Fig. 49. It consists mainly of a large number of wrought-iron or steel tubes T, which are inclined at an angle of about 15° to the horizontal. The tubes are connected at each end to manifolds, or *headers*, H, and seven or eight of these vertical rows of tubes are placed side by side. Each header is connected to the steam drum B by tubes C, C. The water flows towards the front headers and passes up into the steam drum, where the steam bubbles are liberated. The return current

flows down through the tubes C into the rear headers. The circulation is very rapid, and the only place where mud or sediment has any chance to lodge is in the mud-drum D. The hot gases are compelled to pass over the tubes crossways three times, by means of firebrick partitions S and the suspended wall K.

The feedwater is introduced through the feedpipe E. The steam is collected in the dry pipe F, which terminates in the nozzles M and N, to one of which is attached the main steam pipe, and to the other the safety valve.

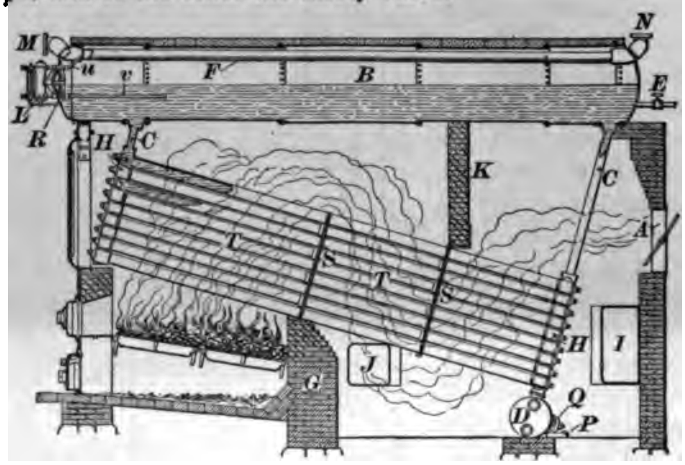


FIG. 49.

The pressure gauge, cocks, etc. are attached to the column, which communicates with the interior of the shell by the small pipes u and v, the former of which extends into the dry pipe, the latter into the water.

The method of supporting the boiler is not shown in the figure. The usual method is to hang the boiler from wrought-iron girders resting on vertical iron columns. The brickwork setting is not depended upon as a means of support. This make of boiler, in common with many others of the water-tube type, requires a brickwork setting to confine the furnace gases to their proper field. Boilers of the water-tube type are well adapted to the supply of steam for both power and

heat. There is a great variety of water-tube boilers made, but the general principles are about the same in all.

127. A modern type of **cast-iron sectional boiler,** for low pressure only, is shown in Figs. 50 and 51. There are

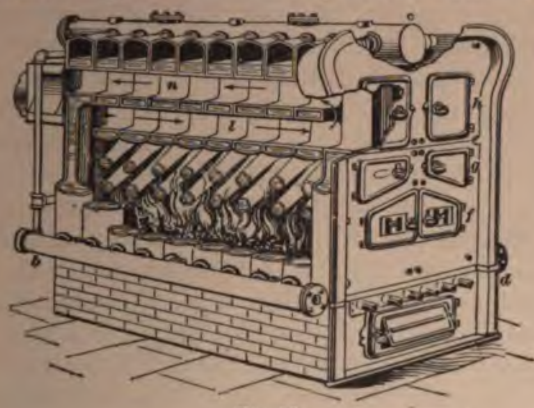


FIG. 50.

no direct connections from one section to another, but each one is independently connected, by suitable nipples, to a steam drum *c*, and to the feedpipes or mud-drums *b* and *d*. A pair of sections is shown in detail in Fig. 51. The water circulates freely in each section, passing up the inclined tubes *k*, and descending through the channel in the outer rim of the section. The hot gases impinge upon the tubes *k* and pass between them to the rear-end section. They then pass forward to the front through the passages *l*, and return to the rear through the upper passages *n*. An advantageous feature of this construction is the fact that each section is practically an independent boiler, and is provided with good circulation.

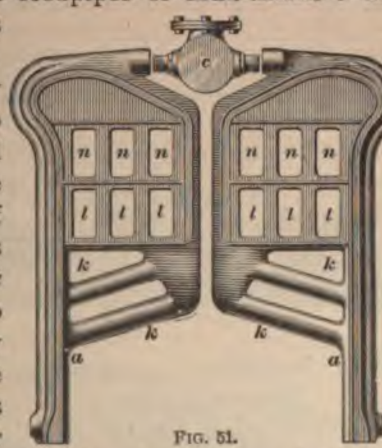


FIG. 51.

HORSEPOWER.

128. Horsepower of a Boiler.—This phrase was originally intended to mean that a boiler having a certain stated *horsepower* would furnish all the steam which was required to develop that amount of power in an ordinary engine, the standard engine at that time being a plain slide-valve engine, using about 30 pounds of steam at 70 pounds gauge pressure per horsepower per hour. Subsequent improvements in engines, however, have greatly reduced the amount of steam required, being as low as 13 pounds in some of the best engines. The term has thus lost its original meaning. To remedy this defect, the American Society of Mechanical Engineers has adopted a new definition, which is, that *one boiler horsepower equals 33,330 B. T. U. per hour, absorbed and transmitted from the fuel to the steam or water.*

Boilers are also rated by their ability to evaporate water from, and at, a temperature of, 212°, 30 pounds per hour being reckoned as 1 horsepower. This method, however, is merely an indirect way of arriving at the number of heat units transmitted through the boiler, and has no particular advantage. The method given, of rating by the number of heat units actually transmitted per hour, enables all varieties of steam and hot-water boilers and hot-air furnaces to be compared directly, without further computation.

HEATING SURFACE AND GRATE AREA.

129. The **amount of heating surface** required per horsepower varies greatly in different kinds of boilers. The following are the heating surfaces commonly allowed:

	Square Feet.
Cylinder	6 to 10
Return tubular	14 to 18
Vertical tubular	15 to 20
Water-tube	10 to 12
Locomotive	12 to 16
Cast-iron sectional	10 to 14

In practice, the rate of heat transmission per square foot of heating surface varies from 800 B. T. U. per hour and upwards, in cast-iron sectional boilers for domestic heating, to 15,000 B. T. U. per hour in the high-pressure water-tube boilers used in torpedo boats.

The actual heating surface of a boiler includes all parts which have water on one side of the metal, and *gas having a higher temperature than the water* on the other. Surfaces which are in contact with steam only have very little value as heating surfaces.

130. The area of grate required in any given case depends almost entirely upon the type of boiler employed, and the rate of combustion. Assuming that the heating surfaces are ample for the work to be done, the proper area of the grates, in square feet, may be computed by multiplying the horsepower of the boiler by certain factors, which are as follows:

Cylinder boiler	.60
Flue	.45
Return tubular	.50
Water-tube	.30
Vertical	.65
Locomotive (stationary)	.40

These factors are suitable for a rate of combustion of about 12 pounds of coal per square foot, per hour, and should be modified for other rates.

Practice has shown that, with this rate of combustion, the ratio of heating surface to grate surface, in a return-tubular boiler, should be about 45 to 1 with bituminous coal, and 36 to 1 with anthracite.

BOILER SETTINGS.

131. The walls which constitute a boiler setting have several duties to perform: *first*, in many cases, to sustain the weight of the boiler and maintain it in position; *second*, to confine the fire and properly direct the hot gases; *third*, to prevent loss of heat as much as possible.

In setting a boiler the following points should be carefully observed:

1. Brick walls are always subject to distortion when exposed to heat, and, if not carefully confined, will become cracked and bulged so much out of shape that they will not properly support the boiler. Therefore, they must be well bound by means of **buckstays** and **tie-rods**, as in Fig. 47.

2. The best practice is to suspend all large boilers from horizontal wrought-iron girders by adjustable hangers, and to support the girders upon wrought-iron posts which are practically independent of the brick walls. When the shell is supported by brackets, as in Figs. 46 and 47, the brackets should rest upon rollers, so that the shell may expand and contract freely. The rollers should bear upon stiff iron plates which are firmly embedded in the brickwork.

3. No part of the boiler which is not covered with water at all times should ever be exposed to the hot gases. In other words, the fire line should always be below the *lowest* water level.

4. All parts of the walls which are exposed to fire or hot gases should be faced with firebrick of good quality. The lining should be not less than $4\frac{1}{2}$ inches thick, and should be so laid that it can be easily renewed without destroying the main walls.

5. The walls enclosing a boiler must be made independent of all other walls, so that they can expand and contract freely. They must never be bonded into the walls of a building, nor into a brick smokestack.

6. The exposed parts of a boiler should always be covered with some good non-conducting material, to prevent loss of heat. Cylindrical boilers may be arched over with brick if desired. The brick should not touch the shell, but should stand off about 1 inch.

7. Cylindrical boilers which are not provided with good feedwater purifiers should be set on an inclination of about 1 inch in 10 or 12 feet, the end over the fire being highest. The mud and sediment will then gravitate towards the rear

end, and the tendency to form scale on the plates over the fire will be reduced.

8. *Cleaning doors* should be provided, which will give easy access to all the heating surfaces of the boiler that are liable to become covered with soot or dust, and to all parts of the flues which may accumulate soot or ashes. If the spent gases are conveyed to the stack through iron pipes, manholes with tight covers should be provided at intervals, so that the entire length of pipes may be easily brushed out.

BOILER FITTINGS.

132. The **safety devices** in common use consist of *safety*, or *relief*, *valves*, to relieve the boiler of excessive pressure, and thus prevent explosion; *low-water alarms*, to notify the engineer, by a whistle, when the water is too low in the boiler, and thus prevent overheating of the boiler plates; and *fusible plugs*, which are so constructed and attached to the boiler that they will burn out and thus allow steam and water to blow into and extinguish the fire before any damage is done to the boiler by overheating dry plates.

133. Damper Regulators.—The regulators which are used to control the fire in steam-heating apparatus are essentially different from those used in hot-water and hot-air heating. In the former case, the regulator is actuated by variations in the *pressure* of the steam; but, in the latter cases, the only thing available for governing purposes is variation in the *temperature* of the heating agent.

The damper regulators used in steam heating are of two kinds, one being operated by a flexible diaphragm and the other by a piston. The former is used on low-pressure boilers, and the latter for high-pressure, or power, boilers.

134. Boiler Feeders.—The boilers attached to steam-heating apparatus are usually replenished by returning all the water of condensation to them, the pipes being arranged so that it will flow back by gravity. When this is impracticable, the water is returned by means of a *steam pump*, a

return trap, or a *steam loop*. When fresh feedwater is required, it becomes necessary to employ either a steam pump or an *injector*, if the water pressure is not greater than the boiler pressure.

FITTINGS AND APPLIANCES USED IN STEAM HEATING.

TRAPS FOR STEAM AND AIR.

135. A **steam trap** is a device for retaining the steam in a heating apparatus while permitting the water of condensation to escape.

136. Fig. 52 shows a **bucket trap** in section. Water of condensation flows by gravity into the trap body *a* through the inlet pipe *b*, as shown by the arrow. As the water rises in the trap, it floats the empty pot, or bucket *c*, and the spike valve shown in the center of the pot bottom is forced into the opening at the base of the tube *i*, which leads through *e* to the outlet pipe *d*, and which is really the outlet opening of the trap.

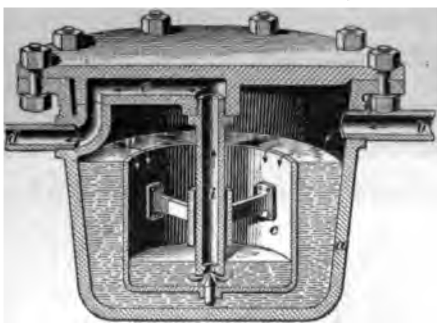


FIG. 52.

When the float has risen to its full height, that is, when the spike valve has reached its seat, the water continues to flow into the trap and will finally overflow into the pot. When the pot is nearly filled with water it loses its buoyancy and sinks to the bottom of the trap, thereby opening the spike valve, but, as the lower end of *i* is now submerged in water, it follows that steam pressure within the trap will force the water in the pot up and out through *i*, *e*, and *d*, to the point of discharge. Before the water becomes low enough in the pot to expose the valve opening to the steam,

the pot again rises and the spike valve closes the opening as before, and the trap again fills with water, only to be partly emptied when the pot is again sunk with an overflow of water into it. It will be observed that the action of this trap is thus *automatic* and *intermittent;* also that the steam pressure in the trap must be greater than that of the atmosphere, otherwise the water cannot be discharged to the outer atmosphere without the aid of some other contrivance, such as a pump, which will draw it, as it were, from the trap and force it into a space of higher pressure—a sewer, for instance.

AIR VENTS.

137. All air vents or traps on steam-heating systems are thermostatic in principle, and are controlled by a difference in temperature between the steam and the air which is to be expelled from the heating apparatus.

Fig. 53 shows a simple form of **air vent.** The shank *a* is screwed into a radiator tube, and the nozzle *d* is connected to a suitable drip pipe. The valve *c* is a rod composed of some expansible material which is adjusted against the steam orifice by means of the screw *b*. When air instead of steam enters the orifice *e*, the rod *c* cools off and shortens slightly, thus opening the orifice and permitting the air to flow through. As soon as hot steam arrives, however, the rod expands, and again closes the vent.

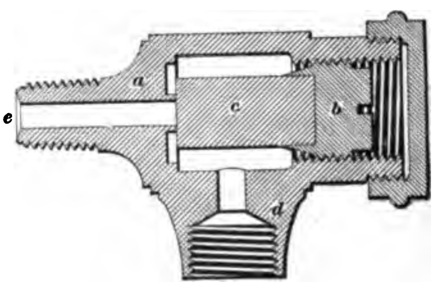


FIG. 53.

The length of the expansible element which is exposed to the air or steam is very small, consequently the opening of the vent will be very slight, and the operation will be quite slow. There are many different forms of air vents on the market, but in principle they all resemble that shown in Fig. 53.

VALVES.

138. Radiator valves, if possible, should all be globe-body compression-angle valves with wood wheel handles. They are usually nickel plated. A brass ground *union connection* should be made between the valves and the radiators.

139. Valves on *steam pipes* should all be globe valves, particularly when high-pressure steam is used. The valve stems should always, if possible, be horizontal, or nearly so. This will prevent water from gathering at the back of the valve. Valves on *return pipes* which are full of water, may be either globe valves or gate valves. The latter usually are preferable.

140. Reducing valves are used for reducing steam from any given pressure to a lower pressure. There are three classes of reducing valves, which are distinguished by their mode of operation: *first,* those which maintain a *uniform low pressure* at the outlet, regardless of the fluctuations of the original pressure; *second,* those which maintain only a *constant difference* in the pressures at the inlet and outlet; *third,* those which maintain a *constant ratio* between the initial and reduced pressures. For all purposes of steam heating, the first mentioned class is the best. They are constructed with balanced valves.

PIPING SYSTEMS.

141. The principal systems of piping which are now in vogue for heating purposes are shown in Figs. 54 to 57. These diagrams are intended to illustrate only the general arrangement of the piping, and many details are therefore omitted. The radiators *a, b, c* are supposed to be located on different floors and at various distances from the vertical supply pipes or risers. It will be seen, by careful inspection of the diagrams, that the main difference between the several systems consists in the method of returning the water of condensation to the boiler.

142. The one-pipe system is shown in its simplest form in Fig. 54. Steam flows from the boiler B through the riser s, and is conveyed to the radiators through suitable branches, which are nearly horizontal. All the water of condensation flows backwards through the same pipes, moving in a contrary direction to the steam. All of the nearly horizontal pipes, such as h and e, must, therefore, be inclined back to the boiler sufficiently to secure the ready movement of the returning water.

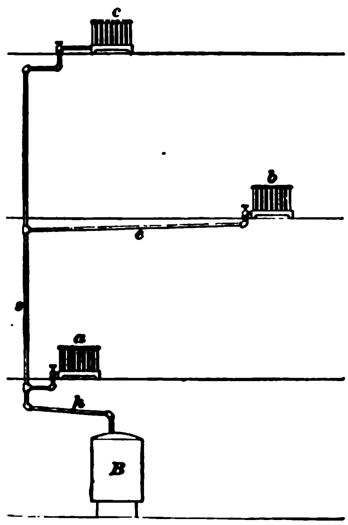


FIG. 54.

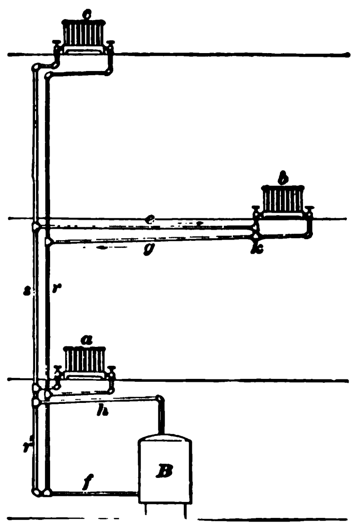


FIG. 55.

143. The two-pipe system is illustrated in Fig. 55. Each radiator has two connections, one of which serves as an inlet for steam, and the other as an outlet for water. The steam supply passes through the pipes h and s, and the water flows back to the boiler through the return pipes r and f. The branch e which supplies steam to the radiator b, at a considerable distance from the riser, is inclined so that the water formed within it will flow towards the radiator. It is connected at k to the return pipe g by a small relief pipe, so that the water will be drained off and prevented from entering the radiator. The steam main h is also inclined, if it is

of any considerable length, so that the water formed within it will run towards the foot of the riser *s*. All of the water formed in the pipes *h* and *s* is drained off by the *relief pipe r'*. Thus the steam and the water are carefully separated at all points in the system.

144. The **separate-return system** is shown in Fig. 56. The steam-supply pipes are the same in every respect as in

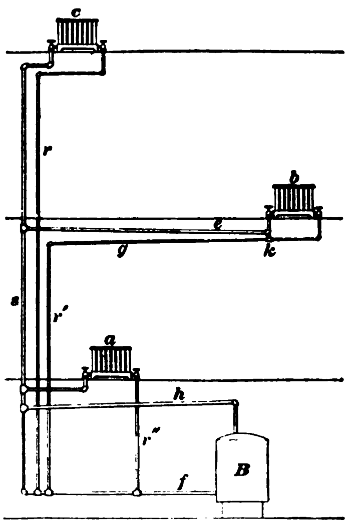


FIG. 56.

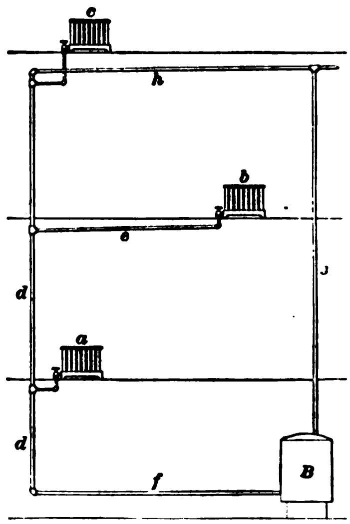


FIG. 57.

Fig. 55. The returns, however, are different, each radiator being provided with its own separate return pipe, as shown at *r*, *r'*, *r"*.

145. The **drop system** is shown in Fig. 57. The steam supply passes up the riser *s* to the top of the system, thence along the horizontal pipe *h*, and descends through the drop pipe *d*. The radiators are connected to the steam supply with single pipes, precisely as in Fig. 54. It will be seen that the water in the pipes *h* and *d* moves in the same direction as the steam, instead of in the opposite direction, as in the single-pipe system. It is not necessary that the returns should be made parallel with the steam-supply pipes, as the

are shown in Figs. 55 and 56, but they may follow any convenient route back to the boiler. It is always advisable, however, to make the returns as direct as practicable, care being taken, however, to avoid straggling the pipes about the building in an unsightly fashion.

146. The circulation—that is, the supply of steam—is far more certain in the two-pipe system than in the one-pipe system, because there is nothing to oppose or interfere with it at any time. Thus, a radiator at the end of a long horizontal branch, as at *b* in Fig. 54, is liable to have its supply interrupted by the formation of the returning water into "slugs," which fill the bore of the pipe and cause hammering noises; but, when the pipes are arranged as in Fig. 55, the same formation may happen without causing any trouble whatever.

147. Occasionally a radiator will gradually fill up with water. This occurs, in a one-pipe system, when the steam valve remains nearly closed for a considerable time, but not shut tight. The steam is then condensed as rapidly as it enters, and the opening is so restricted that no water will escape. The same thing will happen in a two-pipe system if either of the valves is closed and the other remains open. By opening both valves wide the water will almost noiselessly pass out into the return, but in the one-pipe system, as soon as the valve is opened, a violent struggle will begin between the entering steam and the escaping water. The result will be a succession of rumbling, hammering, and snapping noises, which will continue for several minutes. If the supply pipe is long, as at *c* in Fig. 54, the noise is likely to be prolonged to an annoying extent.

148. It is advisable to divide all heating systems which are of any considerable extent, into several independent sections. Long or troublesome horizontal branches may be reduced to a minimum by employing independent or special risers, and carefully locating them where they will supply the largest number of radiators to the best advantage. One riser may be used to supply almost any number of radiators,

provided that none of them are located so far away from it as to make it difficult to drain the supply branch. Thus the question of the number of risers to be employed will be determined mainly by considering the drainage in the horizontal pipes.

Each section of a heating system should be made *independent* of the others, so that it can be closed down for repairs without affecting any other part of the system. Valves should be placed, in both the supply and return riser connections, close to the mains.

DESIGNING A PIPE SYSTEM.

149. In planning any system of steam pipes, there are two things to be kept always in mind and which must be fully provided for; these are **drainage**, and the movement of the pipes by **expansion**. No heating can be done without condensation, and the water thus produced must be disposed of promptly and completely, and in a manner which will prevent interference with the steam supply.

150. The general arrangement of a **steam main** to supply several risers is shown in Fig. 58. The boiler *a* is set on the cellar or basement floor, and furnishes steam to the entire system. The steam main *b*, whose office it is to convey steam to the several risers *c*, through which it flows to the radiators *d*, *d*, etc., placed within the rooms to be warmed, is connected to the steam space of the boiler, and is so suspended from the floor joists by hangers that it will have a uniform fall from its highest point, which is immediately above the boiler, to its lowest point *f*. A pitch of about $\frac{1}{2}$ inch in 10 feet is usually considered sufficient fall for the main. When steam is generated in the boiler it is forced into the steam main, from there into the risers, and thence into the radiators. The air which the pipes contain is forced out of the system to the atmosphere through air vents placed upon each radiator at the end opposite the steam inlet. As steam flows through the main and the

risers, part of it will be condensed by heat being transmitted through the pipes to the air and to objects surrounding them.

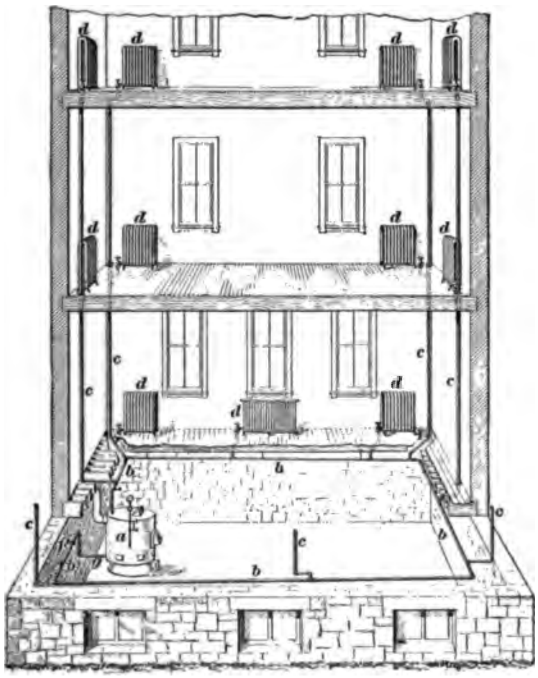


FIG. 58.

This condensed steam will fall by gravity to the bottom of the steam main, flow to its lower end *f*, and enter the bottom of the boiler through the return pipe *g*.

151. The water of condensation from the radiators first accumulates in the base of the radiators until a sufficient hydrostatic head is formed to cause it to flow out of the radiators against the inflow of the steam. It then falls down the risers, through the riser connections, and into the steam main, also against the flow of the steam. If the riser connections to the steam main, or radiator connections to the riser, have too little pitch, or if the pipes are too small, the flow of the water of condensation through them will be

resisted so much by the flow of steam that the water will [illegible]t flow off as quickly as it is formed, the result of which will simply be that the water will accumulate in the pipe until it is entirely closed, and then water hammer will take place. The steam main should be made sufficiently large to prevent such a difference between the pressure in the boiler and that at the point *f*, as would cause the water to back up in the main and retard the flow of steam to any riser connection.

152. When a main or any horizontal steam-supply pipe has to be run a long distance, it becomes impracticable to grade it uniformly throughout its whole length, because the far end drops too low to be drained conveniently. In such a case the difficulty may be overcome by introducing *vertical offsets*, or *relays*, in the line of pipe. A relief pipe may then be attached at the foot of each relay to drain off the water of condensation.

153. The **riser connections**, or the nearly horizontal pipes between the steam main and the foot of the risers, in one-pipe systems, may be made as shown in Fig. 59. This permits the main to be kept away from the foundation wall sufficiently to allow it to be got at conveniently for screwing together and also for putting on coverings, etc.

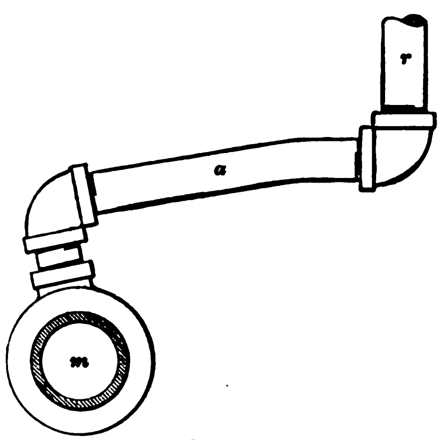


FIG. 59.

The piece *a* serves as a spring piece, and permits both the main and the riser to shift slightly by expansion. In Fig. 59 the spring piece is bent, to insure good drainage. The construction shown in Fig. 60 is sometimes used for the same purpose, the grade being secured by

cutting the thread crooked at the end *a*. This is bad practice, because the teeth of the dies cut too deeply into the pipe on one side and weaken it seriously.

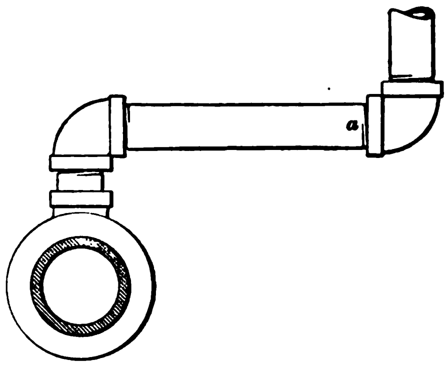


FIG. 60.

154. A riser should not be connected directly into the top of the main by a **T**, unless both pipes are very short. If the riser is long, its weight will cause the main to sag, and if the connections to the radiators above are rigid, the downward expansion will either bend the pipe or lift the radiators.

155. The connections to radiator branches, etc. should, if possible, be made with **Y** fittings. Plain **T** connections are objectionable in a one-pipe system, because the water of condensation runs down upon the interior surface of the riser, and is very apt to flow outwards into the branch, thus increasing the difficulty of draining it properly.

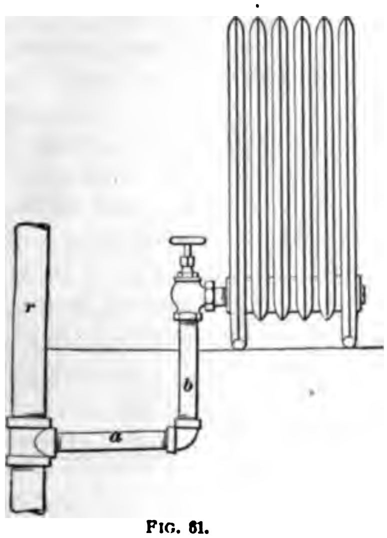


FIG. 61.

156. Radiator Connections.—The ordinary mode of connecting a radiator to the riser in a one-pipe system is shown in Fig. 61. The pipe *a* serves as a spring piece to allow the riser to expand without lifting the radiator, and the drop *b* insures that the water

shall drain away readily. If the radiator is located close to the riser *r*, the valve should connect to the other end of the radiator.

157. Returns.—The downward grade given to return pipes should be uniform, as nearly as practicable. There should be no upward bends or loops, because air is likely to collect in them and impede the flow of the water.

When the returns are connected to a main which is located above the water level of the boiler, the arrangement is called a **dry return.** If there is any perceptible difference in the pressures at the various radiators thus connected, the steam will flow backwards, through the return pipes towards the points of lowest pressure, and in most cases will spoil the drainage and cause water hammer.

158. When the return main is located below the water level, it is called a **wet return,** and the water which it contains acts as a barrier to prevent the passage of steam from one return to another. Thus the steam is compelled to pass through the system, in the direction it was intended to go, instead of making a short circuit or by-pass.

159. Water Level in the Returns.—There is always more or less difference in the pressure of the steam in the boiler and at the end of a line where the return is connected; therefore, the water will rise in the return to a height above the water level in the boiler sufficient to balance the difference in pressure. As this difference varies in the several returns, the water is likely to stand at different heights in each. The hot water rises about 29 inches for each pound of difference in pressure. In a properly designed heating system this difference in pressure should not exceed 1 pound.

SIZE OF PIPE REQUIRED.

160. The proper size of pipe is one which will furnish a sufficient amount of steam without undue fall of pressure, and at the same time will not present an unnecessary amount of surface of condensation.

It is found in practice, when steam having a pressure less than 5 pounds, by the gauge, is employed, that the proper sizes for **branches** to radiators are about as follows:

ONE-PIPE SYSTEM.

Heating Surface of Radiators.	Diameter of Pipe.
24 square feet or less	1 in.
Above 24, not exceeding 60 square feet	1¼ in.
Above 60, not exceeding 100 square feet	1½ in.
Above 100 square feet	2 in.

TWO-PIPE SYSTEM.

Heating Surface of Radiators.	Steam.	Return.
48 square feet or less	1 in.	¾ in.
Above 48, not exceeding 96 square feet	1¼ in.	1 in.
Above 96 square feet	1½ in.	1¼ in.

161. The preceding data apply to *direct* radiators; when indirect radiators, which condense more steam per square foot, are used, the area of the pipes should be increased to about as follows:

Heating Surface of Indirect Radiators.	Steam.	Return.
30 square feet or less	1 in.	¾ in.
From 30 to 50 square feet	1¼ in.	1 in.
From 50 to 100 square feet	1½ in.	1¼ in.
From 100 to 160 square feet	2 in.	1½ in.

162. The size of **steam mains**, or **principal risers**, may be computed by the following rule:

Rule 10.—*Divide the amount of direct heating surface in square feet by 100; divide the quotient by .7854 and extract the square root of the quotient thus obtained; the result will be the diameter of the pipe in inches.*

EXAMPLE.—What should be the diameter of a main steam pipe to supply direct radiators having a total heating surface of 3,800 square feet?

SOLUTION.— $\sqrt{\frac{3,800}{100} \div .7854} = 6.9$ inches; in practice a 7-inch pipe would be used.

163. To find the amount of radiator surface which may be properly supplied by any given size of pipe, the reverse process should be followed:

Rule 11.—*Multipy the square of the diameter of the pipe in inches by .7854; then multiply the result by 100; the result is the total amount of heating surface, in square feet, which the pipe will supply.*

EXAMPLE.—What amount of direct heating surface may be supplied by a steam pipe 7 inches in diameter?

SOLUTION.— $7^2 \times .7854 \times 100 = 3,848$ square feet, nearly. Ans.

PIPING A BUILDING.

164. New buildings are piped while the work of construction proceeds, as soon as the walls are up, and the roof is on. On large jobs, the risers are usually put up first, then the horizontal branches are constructed, proceeding always from the riser back towards the radiators, and lastly the mains are put in place. The returns are constructed at the same time, and in a similar manner.

In many cases, however, particularly in small buildings, the mains are run in first, then the risers, and finally the radiator connections. This latter method avoids the use of *right and left* fittings, or unions, between the risers and the mains.

All radiator connections should be promptly *capped* as soon as erected, and all openings in T's and other fittings should be plugged at once, so that no dirt may get into the pipes.

165. During erection, the matter of *expansion* must be carefully considered. The best point for fastening each principai pipe, so that its expansion will cause the least disturbance, should be determined by close examination. Care must be taken to have every such pipe *free* at its ends, and to see that its connections or branches are not bound or rendered immovable by plaster, brick, wood, or iron beams or columns.

166. The piping should be tested for tightness, before it is covered by plaster or flooring, so that if any defective fittings or split pipes are discovered, they may be replaced without trouble. The *testing* is done by filling the system full of water, every opening being tightly closed, and then applying pressure by means of a force pump. The pressure is increased until the gauge shows from 100 to 150 pounds per square inch. Another test should be made, with steam, before the pipes are covered up, if possible. This will determine whether the expansion is properly provided for, and whether the system is in working order. The steam pressure used should not greatly exceed the proposed working pressure.

167. All steam pipes should be kept out of contact with woodwork or other combustible materials. A clearance of

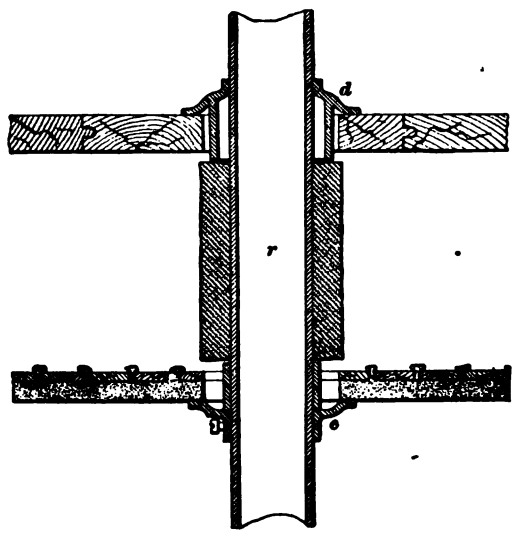


FIG. 62.

at least two inches should be maintained at all points, and where this cannot be had, special protection should be provided. Return pipes are liable to be full of hot steam at times, therefore they must be guarded the same as steam-supply pipes.

Fig. 62 shows the manner of using **floor** and **ceiling flanges** to protect the woodwork where a steam pipe passes through an ordinary floor. When the ceiling flange *c* is secured to the pipe by a setscrew, as shown, allowance must be made in setting it for the vertical expansion of the pipe, otherwise it will be liable to break the plaster forming the ceiling. A better construction is to connect the upper and lower flanges by a nipple, a size or two larger than the riser, and have a current of air flowing through the spaces between the pipes and any combustible material.

TYPES OF HEATING SYSTEMS.

168. The various systems of steam heating now in vogue may be divided into four classes, according to the pressure of the steam and the manner in which it is used in them.

The **high-pressure** system is operated with steam at any pressure above 10 pounds by the gauge, or thereabouts. The radiators require less heating surface, and the piping may, in some cases, be made a size smaller than for pressures of 2 to 5 pounds. The fall of pressure that may be permitted at the radiators is, however, no greater than in a low-pressure system, therefore the size of the piping cannot be reduced to any considerable extent. This system requires a better class of steam generators, which are more costly than low-pressure generators, and the radiators also require to be made extra strong. High-pressure heating is seldom used, and is not to be recommended for domestic work.

169. The **low-pressure** system is usually operated with pressures ranging from 2 to 5 pounds above the atmosphere. This system is most commonly employed, and is the one referred to in this section, unless otherwise stated.

170. The **exhaust** system is in every respect a low-pressure system, except that it is provided with special apparatus which adapts it to receive the exhaust steam from engines and pumps.

The exhaust system is used for the purpose of utilizing and saving the heat in exhaust steam which would otherwise go to waste. A pound of exhaust steam at 5 pounds gauge pressure, and a pound of live steam at 60 pounds pressure, will give up practically the same quantity of heat when condensed in the radiators. The practice of allowing exhaust steam to escape into the atmosphere in any situation where it can be used in heating apparatus, either for house warming or heating liquids, etc., is, therefore, inexcusably wasteful.

171. The general arrangement of apparatus for controlling the steam supply and drainage, in an exhaust system, is shown in Fig. 63. The steam-heating main *a* is connected to the exhaust pipe *b*, and also to a pipe *c* which supplies live steam from the boilers. This steam passes through a pressure-reducing valve *e*, and is lowered in pressure to the desired amount before entering the heating main. By this arrangement the heating system will be supplied with exhaust steam as long as the engines are in operation, but if for any reason the supply becomes insufficient to maintain the proper pressure, then live steam will enter through the reducing valve and make up the deficiency. If the supply of exhaust steam becomes excessive, so that the pressure rises unduly, the excess will escape by opening the back-pressure valve *f* and blowing into the atmosphere. When the engines are stopped, the steam in the heating apparatus is prevented from passing backwards and filling them up with water, by means of the check-valve *g*. This valve is similar to the valve *f* in construction, and is so nearly balanced by its counterweight that it will open very easily. The relief valve *f* is usually adjusted to blow off at a pressure about 1 pound higher than that maintained by the reducing valve *e*.

The exhaust steam is passed through a separator *d* before entering the heating system, for the purpose of removing the entrained water, and especially the oil which accompanies it, from the engine.

The drainage from the heating apparatus is collected in the pipe *h*, and is returned to the boiler by means of a pump *p*, as shown. The returns have no direct connection with the boiler, consequently the water level in them may be maintained at any convenient height, as at *i i*. This is accomplished by means of the pump and its governor *m*.

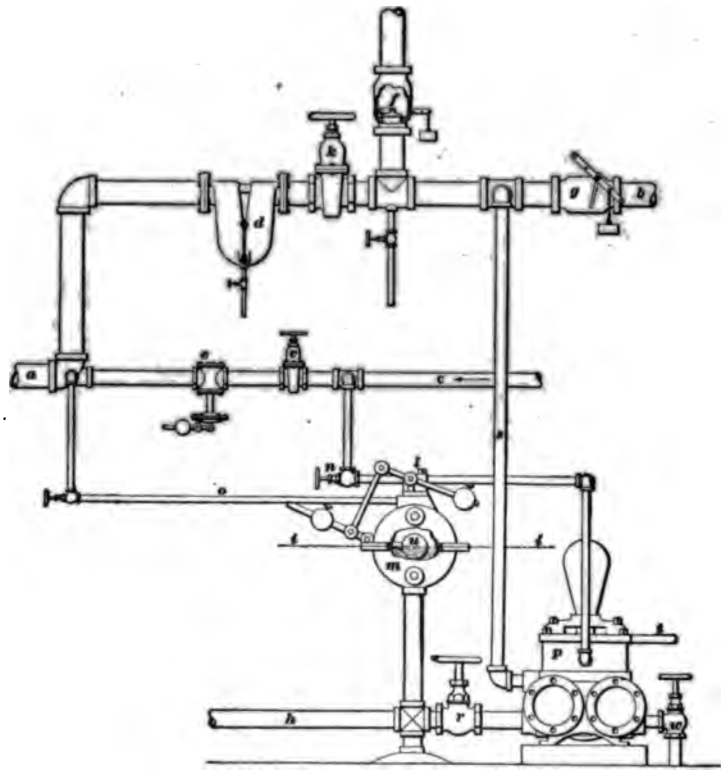


FIG. 63.

The **pump governor** is merely a closed vessel containing a float *u* which rises and falls with the water level. The steam which drives the pump is taken from the high-pressure pipe *c* through the stop-valve *n*, and passes through a throttle valve *l* which is controlled by the float. When the water rises above the desired level, the float opens the throttle and

starts the pump; and when it subsides, the float lowers and shuts off the steam. The exhaust from the pump is turned into the exhaust main through the pipe *s*. The pump governor is connected to the heating main *a* by a small pipe *o*, for the purpose of equalizing the pressure on top of the water therein.

Valves are provided in the main pipes at *k* and *v*, for the purpose of shutting off the heating apparatus during the summer season. It will be noted that these valves are located so that they do not interfere with the supply of steam to the pump, nor with the exhaust therefrom. The returns are shut off from the pump by the valve *r*, and an independent water supply is attached at *w*. The pump delivers through the pipe *t* to the boiler.

Care must be taken to locate the valves *f* and *g* in proper relation to each other, as shown. If the check-valve is placed between the heating main *a* and the valve *f*, and the reducing valve *e* should get out of order, the pressure would rise in the heating system until it equaled that in the boiler. This would probably burst the radiators and do serious damage. The safety of the whole apparatus depends upon the good working condition of the relief valve *f*.

172. The **vacuum system** of steam heating differs from all others in one important particular, viz., a vacuum, more or less perfect, is constantly maintained in the returns. This permits the system to be operated with steam of any convenient pressure, high or low, and from any source, either exhaust or otherwise. The pressure and temperature throughout the whole system may be adjusted and maintained at any degree between full boiler pressure and a low vacuum, thus making the system adjustable to suit all conditions of weather and service.

Usually the system is operated with exhaust steam, the supply being arranged as shown in Fig. 63. The piping is usually arranged on the *two-pipe* system, and the returns are generally made independent, although it is not necessary to do so in all cases.

173. Fig. 64 shows the essential features of the system. The returns *a* are connected to a receiver *b*, which collects all of the air and water in the system. These are pumped

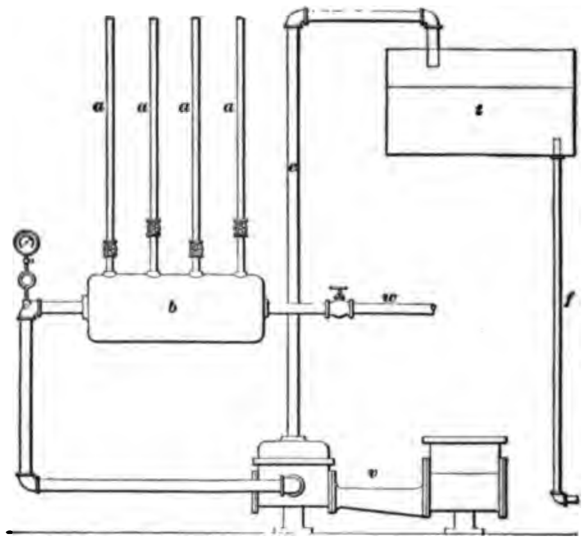


FIG. 64.

out by means of the **vacuum pump** *v*, which thus maintains a constant vacuum of any degree desired in the returns.

By this arrangement any steam may be used in the radiators that is warm enough to operate the traps. It permits steam to be used at a pressure far below the atmosphere, and at any temperature down to about 140°, the limit being fixed only by the ability of the pump to keep up the vacuum in the returns.

The water and air which are drawn from the receiver by the vacuum pump are discharged into an open tank, from which the air readily escapes. The water is then pumped back into the boiler by any ordinary feed pump.

174. In some cases, the fresh, cold water which is otherwise required to feed the boilers, is injected into the receiver in a series of fine streams, through the pipe *w*, the object being to condense as much as possible of the steam which is

present, and thus improve the vacuum. At the same time that the water becomes warmed it gives up the air accompanying it, thus increasing the amount to be removed by the pump. This air expands into the vacuum and partially neutralizes the effect of the condensation. Thus it will be seen that the introduction of the feedwater into the system at this point is of doubtful utility. If it is sent through an ordinary feedwater heater instead, it will become much hotter and the air will be eliminated without difficulty.

175. It will be understood that when the exhaust steam from an engine is turned into the ordinary low-pressure heating system, the back pressure is increased, and the efficiency of the engine is correspondingly decreased, sometimes to such an extent as to become very detrimental.

One of the principal advantages of the vacuum system is that a great part of the back pressure is taken off the engines, and the capacity of the engines to do useful work is thereby increased.

176. The size of the piping required for the vacuum system of steam heating is about the same as for the ordinary low-pressure systems. The radiators, however, must be larger than for any other system, in proportion as the temperature of the steam used is lower.

177. The **district system** of steam heating is practised in large towns and cities by means of steam mains which are laid underground through the streets. The arrangement of the connections from the street mains to the house pipes is shown in Fig. 65. The service pipe *a* is provided with a valve *b* inside the basement wall, so that the house system can be shut off when desired. The steam passes through a pressure-reducing valve *c*, and thence into the distributing pipe or house main *e*. The water that may enter from the service pipe is led away by the drain pipe *d*. The returns are all connected into the pipe *f*, which is submerged below the water level. The level of the water in the returns is

fixed by the elevation given to the steam trap *t*; thus, in the figure, it is at the line *g*. The hot water from the trap should never be discharged directly into the house drains, because of its destructive effect upon the pipes, but should be cooled before escaping to the sewers, by first allowing it to flow through a coil of pipes. This coil is usually called a

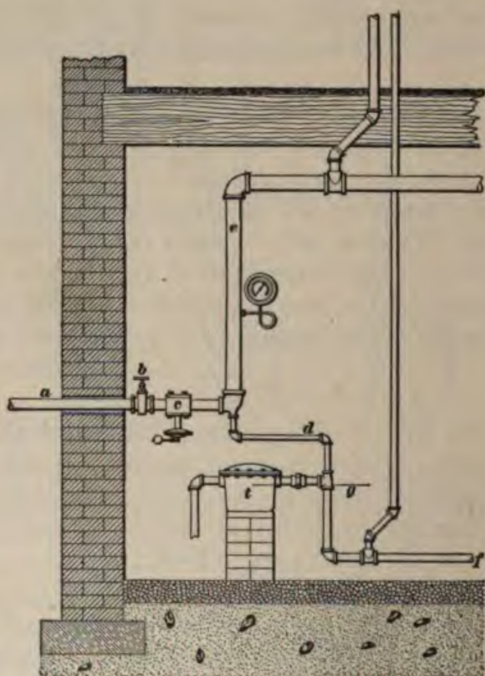


FIG. 65.

cooling coil. It should never deliver directly into the drainage system, but in all cases should deliver into a deep, sealed trap. This is to prevent drain air from entering the heating system or the building. The trap, or hotwell, should always deliver into the house sewer connection on the sewer side of the main-drain trap, to prevent hot vapors from passing up the iron drainage system in the building.

HOT-WATER HEATING.

HEATING APPARATUS.

BOILERS.

178. The boilers used in hot-water heating systems are similar in all respects to the best forms of steam boilers, except that the spaces commonly reserved for steam room may be dispensed with, or be utilized for tubes and other heating surfaces. Thus, in a common *tubular boiler* the entire shell may be filled with tubes.

The circulation inside of a hot-water boiler is quite different, however, and in many parts is likely to be much slower than in a steam boiler. The cold water enters at the bottom, and when heated passes out at the top; the general movement is, therefore, upwards, and there is only a moderate amount of return, or local, circulation within the boiler.

The water should pass from the inlet, over the heating surfaces, to the outlet in the most direct manner and with the least possible resistance.

179. The **area of heating surface** required in a hot-water boiler, for any given transmission of heat, is the same as in a steam boiler working at the same temperatures of water and combustion. The required areas of grates and chimney are also about the same.

The numerous varieties of hot-water boilers now on the market differ greatly in the *volume of water* which they contain, although they may have equal heating power. A heating system which contains only a small amount of water can be heated quickly, but it will also cool quickly; while, if the volume of water is large, it will act as a reservoir of heat and will maintain a moderate temperature for a considerable time after the fire has failed.

180. **High-pressure** boilers are used for heating with hot water having a high temperature and correspondingly

high pressure. They are usually constructed of tubing in the form of a box coil. The tubing is of wrought iron or soft steel about $\frac{7}{32}$ inch thick, and the bore is usually $\frac{3}{4}$ or 1 inch. All the joints on the boiler or heating coils are welded.

High-pressure heaters ought never to contain a large volume of water, because the danger from an explosion will be too great.

181. Draft Regulators.—It is more difficult to automatically regulate the draft in a hot-water heater than in a steam boiler. In the latter case the regulator is operated by the *pressure* of the steam, and the pressure is nearly the same in all the pipes which lead from the boiler. In a hot-water apparatus, however, only the *temperature* varies to any considerable degree, and this change in temperature is employed to regulate the draft. Draft regulators are constructed to operate in many different ways, but the most

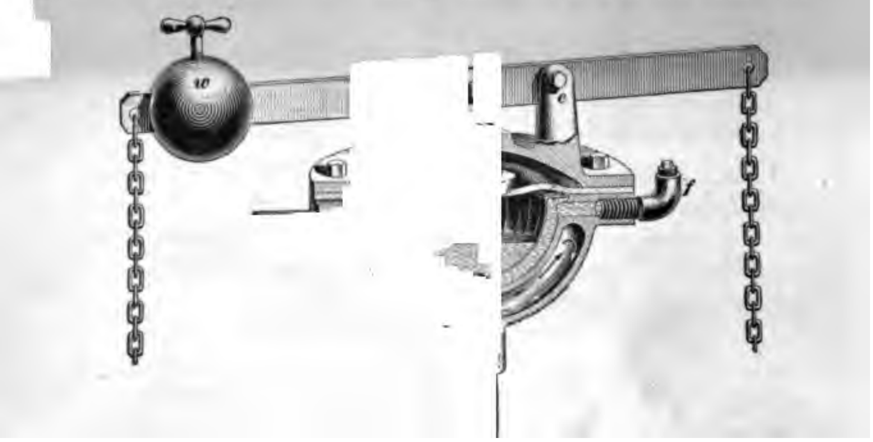


FIG. 66.

efficient class is that which utilizes the expansive force of some volatile liquid, which is acted upon by the hot water passing through the apparatus. A regulator of this kind is shown in Fig. 66. It contains a diaphragm of ordinary construction, which operates the lever *d* in the usual manner.

A large corrugated brass cup, having an aperture at the bottom only, is attached to the under side of the diaphragm. The space between the cup and the bowl is filled with some liquid, as shown, which is more volatile than water, usually a mixture of water and alcohol. The cup is filled only with air or vapor. Hot water from the heater enters the chamber *c* through *a* and returns to the heater through *b*, as shown by arrows. This water heats the liquid and vapor in the bowl and cup. The pressure generated is proportional to the temperature of the water, and is sufficient to properly operate the diaphragm and the apparatus attached to it.

EXPANSION TANKS.

182. The purpose of an expansion tank is to keep the pipes and other apparatus constantly full of water. The water in the heating system expands when heated, and if it fills the apparatus when cold it will overflow it when hot, and the expansion tank serves to receive this overflow.

The capacity of the tank required in any given case depends upon the volume of water in the heating system and the highest temperature which it will attain. In an ordinary system, where the tank is open to the atmosphere, commonly called the low-pressure, or **open-tank**, system, the temperature cannot be raised much above 212°. The capacity of the expansion tank, between high and low water marks, should be about $\frac{1}{20}$ of the total contents of the apparatus to which it is attached.

183. When the water is to be heated to higher temperature, as in the so called high-pressure, or **closed-tank**, system, the expansion tank must be closed and its capacity must be greatly increased. Not only must space be provided for the expansion of the water, but there must be additional space above the water, when expanded to its utmost, sufficient to contain the air which originally filled the tank, without compressing it too much. The pressure of the air thus compressed should not exceed the pressure of

steam corresponding to the maximum temperature of the water.

For example, if the water is heated to 350°, it will expand about .12, or $\frac{1}{8}$ of its original volume, and the tank must have a capacity between high and low water marks equal to $\frac{1}{8}$ of the total contents of the apparatus, including pipes, radiators, and boiler. The pressure of steam having a temperature of 350° is about 120 pounds, gauge. Air must be compressed to about $\frac{1}{8}$ of its original volume to produce that pressure; therefore, the space for air, above high-water mark, in this case should be, at least, $\frac{1}{8}$ of that allowed for expansion.

184. Safety Valves.—In practice, any *closed* hot-water system is liable to be neglected and overheated. The expansive force of the water is practically irresistible, and unless room be provided for the expansion, it will burst the apparatus. The only mode of securing safety is to provide the closed tank with a safety valve. This may be set to blow off at the pressure which steam would have at the maximum temperature desired in the apparatus. *No closed tank should be allowed to operate without a safety valve.*

A hot-water apparatus having an *open* tank is absolutely safe from accident by bursting so long as open communication exists between the tank and boiler. But if the tank is closed for any reason, or its connections are closed, it is thereby converted into a dangerous apparatus.

185. Freezing.—The connection of the tank to the heating apparatus must be carefully protected against frost. When this connection is frozen, the apparatus is deprived of the relief afforded by the tank, and a rupture is sure to occur in some weak part when the water is being heated.

186. Stop-Valves.—Open communication between the expansion tank and the boiler must be maintained at all times. No stop-valve should ever be placed on this pipe, as such a valve is liable to be closed, and thus produce disaster.

187. This construction of an ordinary low-pressure expansion tank is shown in Fig. 67. The body and heads

are made of wrought iron, and should be galvanized inside and out. A glass water gauge *b* is attached to show the height of the water inside. The surface of the water should be visible in the gauge both at its lowest and highest levels. The tank is connected to the heating apparatus by an expansion pipe *c*. A connection to the cold-water house-supply pipe may be made at *e*, for convenience in filling the tank. The top of the tank is always open to the atmosphere through the pipe *d*. *This opening must never be closed.*

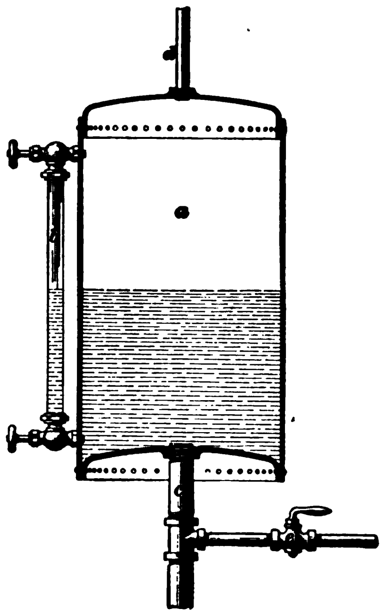


FIG. 67.

188. An expansion tank suitable for high pressure differs from the form shown in Fig. 67 mainly in its proportions, being of smaller diameter in proportion to its length, and it is also made of much thicker materials. The outlet pipe is controlled by a safety valve. The height of the water is usually shown by means of *gauge*, or *try*, cocks screwed into the side. Glass water gauges are not suitable for high-pressure tanks, because they are very liable to crack and burst, and thus allow the water to escape and damage the building.

HOT-WATER RADIATORS.

189. Radiators for hot-water heating should be composed of vertical tubes, and these must be connected with ample waterways at both top and bottom. The continuous pipe coil which is so effective in steam heating, has few advantages when applied to hot-water heating, and is quite

inferior to the vertical loop radiator. The circulation in a coil will gradually stop as air collects in the upper pipes or the header, but it will continue in a vertical loop radiator (see Fig. 68) as long as the level of the water is above the line *a*, in the figure. If it falls, say, to the line *b*, the hot water will diffuse slowly up each side of the loop, while the main circulation passes directly from the inlet to the outlet.

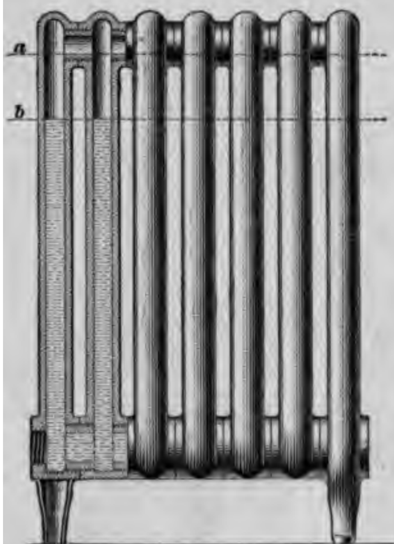


FIG. 68.

The connections of the loops to each other at the bottom should be more than equal in area to the supply pipe, otherwise the resistance will be so great as to seriously impede the main circulation.

190. Hot-water radiators are often made with three tubes in each loop instead of two, and it is supposed that the water will ascend in the central tube and descend in the side tubes. There is, however, no appreciable difference in operation between the three-tube loops and those having only two tubes.

Hot-water radiators must have two connections, one for the inlet and the other for the outlet. They cannot be operated successfully with a single connection. The supply may enter the top or bottom of the radiator, but the outlet should connect at the bottom.

191. In using hot-water radiators for indirect heating, particular care must be taken to prevent them from being frozen by circulation being shut off. The best preventive

is simply to connect such radiators direct to the system without any controlling valves being attached to them. This will insure a constant circulation while a fire remains in the boiler.

FITTINGS, VALVES, AND VENTS.

192. The **fittings** commonly employed in steam piping are objectionable for hot-water heating apparatus, because of the great resistance which they offer to the flow of the water, due to the angles being too abrupt. The enlargements commonly made in pipe fittings are of little consequence when steam flows through them, but they retard the flow of water too much in a hot-water heating system, because the motive force of the current is so small in proportion to the amount of resistance offered. Elbows for hot-water service should be made with a radius equal to five times the internal diameter of the pipe, as shown in Fig. 69. Such **elbows** are commonly made of wrought-iron or steel pipe, bent up to shape, and, consequently, are commonly called **bends.**

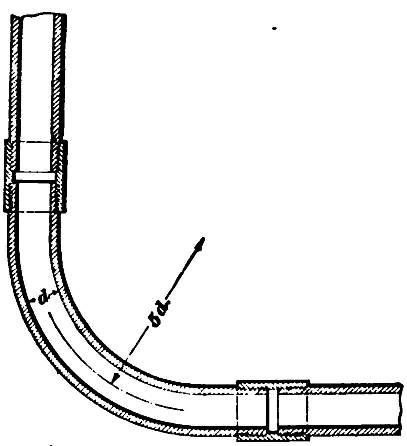


FIG. 69.

When common pipe fittings must be employed, the evil may be mitigated somewhat by carefully reaming out the ends of the pipe. The common *screw* union should never be used in hot-water piping; the right and left coupling should always be employed instead. In large pipes, only the *flanged* unions should be used.

193. The requirements of **valves** used in hot-water heating apparatus are very different from those employed in steam heating or in ordinary plumbing. In the latter cases they must close with sufficient force to be tight against

considerable pressure, but in hot-water heating they require only to check or direct a current of water having but a very small propelling force. The stems must be packed with equal care, however, to prevent leakage, and the valve bodies must be equally strong, to resist static pressure and rough usage; but the valve proper, i. e., the part which serves to shut the passage, may be of very light construction.

Globe valves offer so much resistance to the passage of water that they should not be employed in hot-water apparatus at any point; therefore, gate valves should be used exclusively in all the piping of a hot-water system.

To prevent the water in a radiator from freezing when the radiator is not in use, a common practice is to have a small hole (about $\frac{1}{8}$ inch in diameter) through the valve so that a small circulation will always be maintained in the radiator when the valve is closed.

194. Air Vents.—Any kind of small valve or petcock will serve as an air vent, for hand regulation; but there are many situations where the venting must be performed automatically. In automatic vents the escape valve must be controlled by a float, so that it will remain closed as long as water is present, and will open only when the water is displaced by air. Air vents for steam heating are frequently constructed with a float which serves to close the vent and prevent the escape of water, but the float in a hot-water air vent operates in a very different manner. The buoyancy of the float, when surrounded by water, is depended upon, primarily, to close the valve; therefore, it should be constructed in such a way that it can never fail to be buoyant.

The changes which occur in the temperature of the water in hot-water heating apparatus cannot be utilized to control the air vents.

HOT-WATER PIPING.

195. Water at ordinary temperatures, if exposed to the air, is always charged with a certain amount of air and other gases, which it seems to hold in solution. When water so charged is increased in temperature, the gases are gradually

evolved from the liquid and rise in small bubbles to the surface until the water has reached the boiling point, when all the air will be liberated and steam will form. Now, it will readily be seen that when a fire is first started in a hot-water boiler, air will be liberated from the water and will rise to the highest points of the heating apparatus, where it will accumulate and form **air locks,** if it cannot escape to the atmosphere.

This matter must be carefully looked after in constructing hot-water heating apparatus, because the motive force is so small that it may be easily neutralized and the circulation stopped by an air lock of comparatively small size. Air collects in all high places, such as the tops of radiators, the upper ends of vertical pipes, etc., and these points should always be provided with air vents.

196. All horizontal supply or **flow** pipes should be inclined upwards upon a uniform grade, so that the air will readily flow into the risers. The air in the pipes will then pass up into the radiators or into the expansion tank. If this cannot be done, an automatic air vent of sufficient capacity must be attached to the piping at the highest point. A bubble or small air lock in a circuit will, in many cases, completely stop the circulation.

The manner of running and connecting pipes for hot-water service is substantially the same as for steam heating. The expansion of the pipes by heat must be provided for by using spring pieces, expansion joints, etc. in the same manner.

197. All **horizontal branches** from the flow main should be connected into the top of the main, or at least should be taken off by means of eccentric fittings, which will bring the top of the branch flush with, or a little above, the top of the main, so that all air bubbles may pass freely forwards and not accumulate in the main.

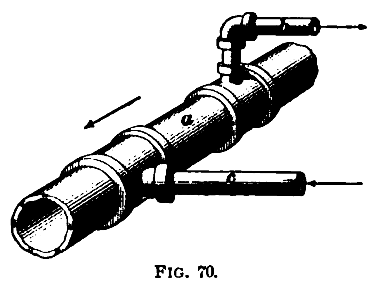


FIG. 70.

198. In the **one-pipe system** the connections for a radiator are made substantially as shown in Fig. 70, *b* being the flow connection, *c* the return, and the main current moving through *a* in the direction of the arrow. The object here is chiefly to take the supply of hot water from the top of the main and return the cooler water into the bottom.

CIRCULATION.

199. The primary cause of the circulation of water by the force of gravity, in a hot-water heating system, is that the liquid becomes denser as it cools off, and it therefore preponderates over the warmer and lighter water and pushes it to the top of the apparatus. It should be clearly understood, that hot water will move only when there is a heavier and cooler body of water to displace it and force it upwards by means of its superior weight, or when some force, other than the force of gravity, is employed to move it.

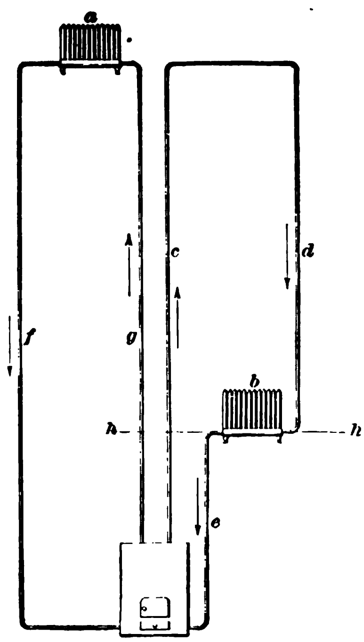


FIG. 71.

The driving force which propels the water in any given circuit which operates by gravity alone, is proportional to the *difference in the mean temperatures* of the ascending and descending parts of the circuit; and does not depend upon the actual quantity of water contained in those opposing parts of a system.

With a given difference in temperatures, it is also proportional to the vertical height of the circuit. Thus, the motive force, or **head,**

in a circuit 50 feet high, would be twice as large as in one only 25 feet high.

200. The force of the circulation through radiators, etc., with a given fall of temperature, depends chiefly upon the height of the *return column*, and is, in many cases, practically independent of the height of the supply column. Thus, in Fig. 71, the circulation through the radiator *a* will be about three times as great as through *b*, notwithstanding the fact that the supply columns *c* and *g* are of equal height, because the return *f* is about three times as high as the return *e*. The temperature in the pipes *c* and *d* is supposed to be nearly the same; consequently, the column *d* simply balances an equal height of column *c*, and fails to supply any force for circulation. The force for circulation in this circuit, therefore, depends upon the preponderance of the weight of water in *e* over the weight of that contained in the riser below the level of the radiator at the line *h*.

It will be seen that the only way in which the drop pipe *d*

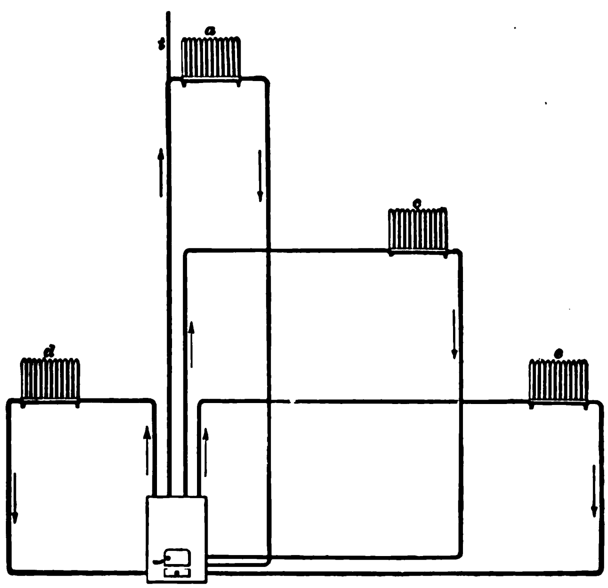


FIG. 72.

can be of service is to act as a *cooler*, and thus lower the temperature of the water which it contains. The same mechanical effect can be obtained, with less expense, by emitting an equal amount of heat from the radiator *b*.

201. A **simple circuit** is one in which the water flows directly to a radiator through a single pipe without branches, and returns to the boiler through another direct and special pipe, as shown in Fig. 72. Although a large number of such circuits may be connected to a single boiler, each one is entirely independent of the others, and the force of circulation is governed by the actual height of each circuit and the difference of temperatures prevailing in it.

202. In a **compound circuit** the supply current moves in a main pipe of comparatively large dimensions, commonly called the *flow main*, and the return currents proceed to the boiler through a similar pipe called the *return main*. These mains are connected by a number of small branches, each of which makes a direct circuit between the flow and return mains. The radiators are connected to these branches, usually one on a branch, sometimes more.

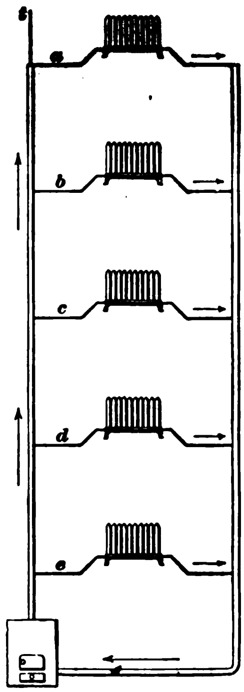


FIG. 73.

Compound circuits are arranged in many different ways, most of which are variations of the two systems shown in Figs. 73 and 74. In Fig. 73 the mains are vertical and the branches are substantially horizontal. In Fig. 74 the mains are horizontal and the radiators are attached to vertical branches or drop pipes.

In the former case, the effect of rapid cooling at any one radiator is to decrease the average temperature of the return main, and, as all the radiators are connected to the same mains,

the effect is divided and distributed over the entire system. In the latter case each radiator is independent, and the rapidity of the circulation through it will depend upon the amount of cooling which occurs at that point.

203. In Fig. 74 the radiators *e* and *d* are supplied from the same **drop pipe,** and both are connected to the same return pipe. The circulation through the upper radiator will always be good, but as long as that one continues in operation, the lower one is likely to fail, being unable to get any hot water. This is due to the fact that the pressure of the cool water in the return between *e* and *d* overbalances that

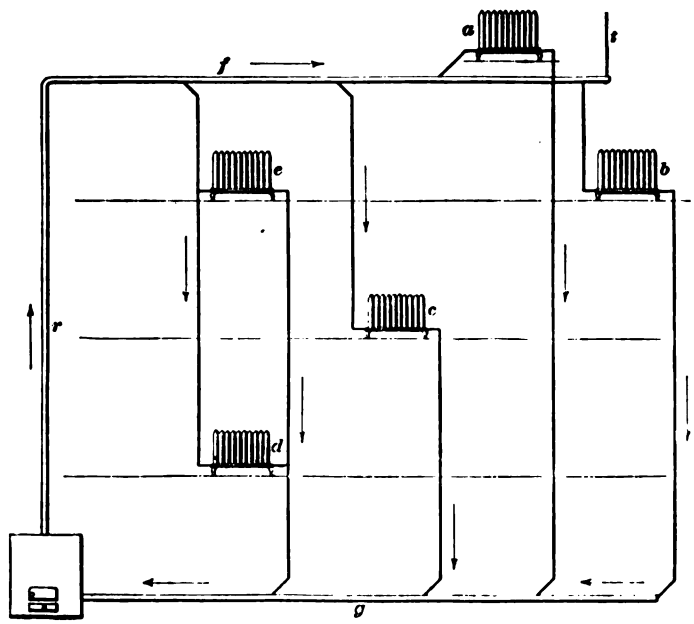


FIG. 74.

of the hot-water column in the flow connection to *d*, and prevents it from flowing through the radiator. The trouble can be remedied, however, by providing it with a separate return connection to the main *g*, thus making it independent of the upper radiator.

204. Another method of operating a radiator on a drop branch, or with a downward moving supply, is shown in Fig. 75. The flow connection to the supply pipe is made at one level, and the return is connected into the same pipe at a lower level. The circulation through the radiator will depend mainly upon the vertical distance between the connecting points *d* and *e*. The flow connection may be made to the top of the radiator, as shown at *a*, or to the bottom, as at *b*, as convenience may require. In the former arrangement each radiator will be supplied with hot water of practically the same temperature, but in the latter case the water in the drop pipe is lowered in temperature by the cooler water which is returned from each radiator; consequently, the water supplied to the radiators at lower levels will be successively reduced in temperature. This will usually make it necessary to employ larger radiators on the lower floors, when this system is employed.

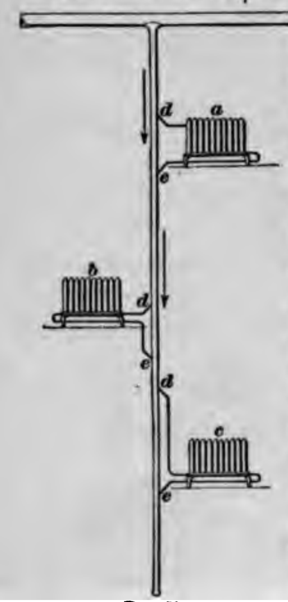


FIG. 75.

OPEN AND CLOSED CIRCUITS.

205. In the plans shown in Figs. 73 and 74, the flow and return mains are connected only by the radiator branches, and there is no way of maintaining a flow of water through them when the radiators are shut off. This arrangement of mains is called an **open circuit.**

206. When all the radiators, except one or two, are shut off, the amount of circulation is likely to be too small to keep the water in the mains at a proper working temperature. Then, when the other radiators are opened for use,

considerable time must be spent in waiting for the whole system to heat up to the desired degree.

This slowness may be obviated by keeping up a good circulation through the mains at all times, regardless of the radiators, by connecting the flow and return mains by a pipe *k*, as shown in Fig. 76. This arrangement is called a **closed**

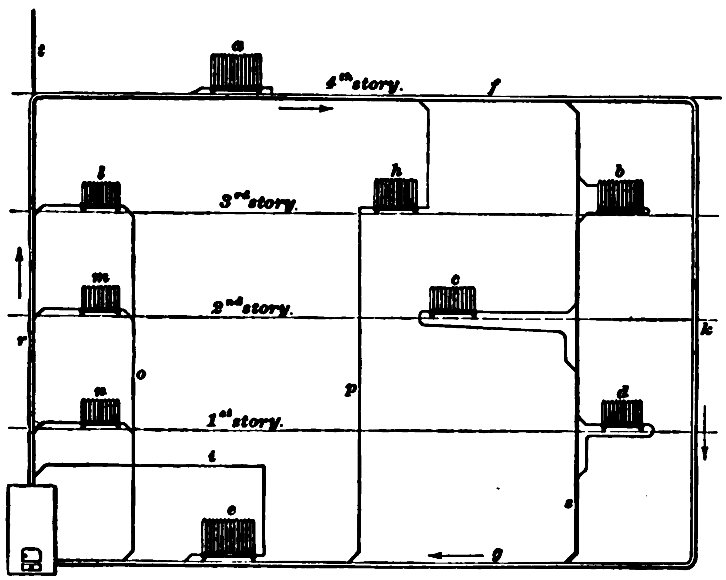


FIG. 76.

circuit. The connection should be large enough to pass as much water as the whole number of radiators when in full operation. As long as a proper fire is maintained in the boiler, an active circulation will go on in the mains, and the water will be always at the maximum temperature, so that any or all of the radiators may be promptly supplied with hot water as soon as the valves are opened.

The closed circuit is desirable for all situations where the simple circuit, Fig. 72, is not used, and is adapted to high buildings as well as low ones. It is superior to all others in long, low buildings, of one or two stories, where the mains

must extend a long distance horizontally, as in cases like Fig. 77.

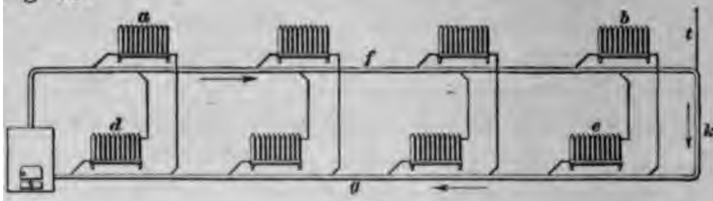


FIG. 77.

NOTE.—There is quite a difference of opinion regarding the true meaning of the terms "open" and "closed" circuits. The terms and the meanings thereof, as adopted by us, may seem contrary to common sense; but they coincide with the meanings of the same words when applied to electrical or other professions, and, therefore, will help to prevent confusion or misunderstanding.

ONE-PIPE OR SINGLE-MAIN SYSTEM.

207. This system is commonly called the **one-pipe** system, but the name is a misnomer. While it is practicable to operate a steam-heating system with a single main, and with single connections to the radiators, it is wholly impracticable to do so with hot water. The nearest approach that can be

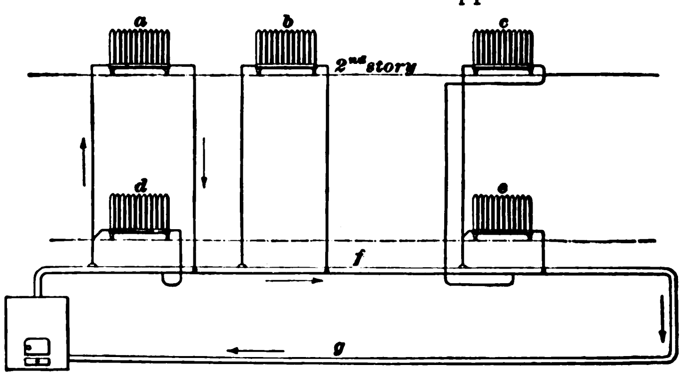


FIG. 78.

made to a one-pipe system of hot-water distribution is to connect both the flow and return branches of the radiators to the same main, substantially as shown in Fig. 78. The main is made of unusually large diameter, so that it acts as

a reservoir, and the current through it is comparatively slow. The risers are tapped into the top of the main, and the returns are connected into the side or bottom, so that they deliver the cooled water into the lower part of the main.

It is necessary that the temperature of the water be maintained at a proper degree throughout the whole length of the main, so that the water supplied to the radiators farthest away from the boiler will be reasonably hot; otherwise, the radiators supplied with the cooler water must be made too large, in order to compensate for the low temperature of the supply.

The main in a one-pipe system is usually carried around the basement walls exactly as for steam heating, and the return connection *g* is made near the boiler.

THE EQUALIZED SYSTEM.

208. It frequently happens that radiators which are located close to the risers and have a free return circulation will take more than their proper share of hot water. This not only diminishes the supply for the more distant radiators, but the water thus passed through is discharged into the return main much hotter than it should be, and the motive

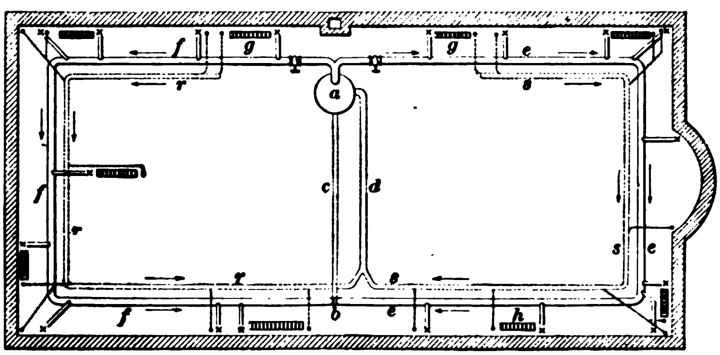


FIG. 79.

force of the system is impaired thereby. To remedy this trouble, the system shown in Fig. 79 is sometimes employed. The distinguishing feature of this system is that the water

is compelled to travel exactly the same distance in going to and from any radiator upon a given floor. Thus, a radiator situated close to the riser will have but little advantage over one situated a long distance away, on the same level.

The flow main is shown divided into two sections *e* and *f*, which extend around the basement walls to the point *b*, where they unite. A return connection is made to the boiler by means of the pipe *c*, thus making a closed circuit. The return mains, however, run in the opposite direction to that usually employed. They begin at the radiators *nearest* to the boiler, instead of the most remote, as in the common way. Thus, they begin at the radiators *g*, and run along parallel with the flow mains, until they finally unite into a single pipe *d*.

It will be seen that the water passing to the radiator *g* runs only a short distance in the flow main; but, since it is obliged to pass through the whole length of the return circuit, the aggregate distance traveled by the water in going to and from the radiator *h* is precisely the same. Thus the frictional resistance to the flow of water to all of the various radiators on the same floor is practically equalized if the pipes are properly proportioned.

PROPORTIONING A HOT-WATER SYSTEM.

209. The principal object to be sought in designing a system of hot-water piping is to adjust and equalize the resistance in each circuit and branch, so that the hot water will flow with equal readiness to each radiator. This is accomplished by making the diameter of each pipe just sufficient to pass the desired amount of water under the *head*, or driving force, which is available in that particular part of the system. Artificial resistances are also introduced at some points by putting in extra elbows or bends, and valves are sometimes used for the same purpose.

The *fall of temperature* of the hot water, as it passes

through a radiator, is usually estimated at about 20° for good practice, and 35° is regarded as the limit in any case.

210. Height of Circuit.—The horizontal pipes on the upper floors of a building, and also the risers leading thereto, may be made smaller in diameter than those upon the lower floors, because the driving force which impels the water increases with the height of the circuits.

The proper size of a pipe having been determined for a given service on the first floor, the diameter for equal service on higher floors, the temperatures remaining the same, may be found by multiplying by the following factors:

Story	2d	3d	4th	5th
Factors	.87	.80	.76	.73

No factors are given for heights above the fifth floor, or about 50 feet, because the decrease for the succeeding stories is so small that it is of little practical account.

211. Conversely, *the area of heating surface that may be properly supplied by a pipe of given diameter will increase as the circuit is made higher.* If the area which is known to be right for a given size of pipe on the first floor be taken as 1, the areas on the upper floors will increase in the following order:

Story	2d	3d	4th	5th
Proper area heating surface...	1.40	1.70	1.98	2.20

212. Resistance of Circuit.—The resistance to the flow, caused by elbows, tees, and other fittings, is considerable. The resistance in a common elbow, the ends of the pipes being left square, is about equal to the frictional resistance of a piece of straight pipe having a length equal to 100 times its diameter. If the ends of the pipes are beveled to an edge, the resistance may be reduced to 70 diameters, or even to 60 in small sizes. With a long bend having a radius of 5 diameters, the resistance falls to 10 diameters, or less.

A plain T offers about the same resistance as an elbow; and a return bend from $1\frac{1}{2}$ to 2 times as much. The gain made by reaming the ends of the pipe is much less in the large diameters than in the small sizes.

The *actual* length of a circuit is always understood to be the actual distance traveled by the water in going from, and returning to, the boiler.

SIZE OF PIPES.

213. There are two methods of determining the proper sizes of hot-water piping, as follows: In the *first method*, the amount of heat to be emitted from the radiators per minute is ascertained and divided by 166.7, which gives the number of gallons of water required per minute with a fall of temperature of 20°. If any other range of temperature is adopted, this divisor must be changed to suit. Having found the flow required, the diameter of the pipes is then computed by the ordinary laws of hydraulics.

214. The *second method* is by the use of tables, which are prepared from data furnished by experience in actual practice, rather than from the data derived from theoretical investigation. It is assumed that each radiator will always operate at its maximum capacity, and that the fall in temperature of the water will be 20°. Therefore, the table is based upon the area of the radiator surfaces, instead of upon the heat units emitted.

The first method is by far the more accurate, but it requires considerable computation, and in practice it is unnecessary that the pipes should be so accurately sized.

The second method is convenient, and is better adapted to the various compound-circuit systems. The error, if any, is always in favor of a freer circulation of the water, so that the fall of temperature will be somewhat less than 20°, and the radiators will then emit a little more heat than rated.

215. Mains.—The following table shows the amount of heating surface that can be properly supplied with hot water by mains of a given size and uniform diameter throughout their whole length, the radiators being located upon the first floor. The fall of temperature is assumed to be 20°, and the height of the circuit is between 10 and 15 feet. The amount of radiator surface that can be maintained on higher floors may be found by multiplying the amount shown in the table by the factors given in Art. **210.**

TABLE 18.

SIZE OF HOT-WATER MAINS.

Diameter of Mains.	Total Estimated Length of Circuit, in Feet.									
	100	200	300	400	500	600	700	800	900	1000
1	20									
1¼	35	20								
1½	56	40	25							
2	116	85	70	50						
2½	220	150	120	100	90					
3	345	240	200	170	150	140	125	110	100	90
3½	500	340	280	245	225	205	190	175	162	150
4	700	485	390	340	310	280	260	240	230	220
4½	925	640	535	460	410	375	345	325	300	295
5	1200	830	700	600	540	490	450	420	400	380
6	1900	1325	1100	950	850	775	700	650	620	600
7		2000	1600	1400	1250	1140	1050	975	925	875
8				1970	1720	1550	1440	1350	1300	1250
9							1900	1800	1700	1620

216. Risers.—Table 19 shows the area of radiator surface, in square feet, that can be properly supplied at various elevations by risers of a given diameter. The radiators are supposed to be connected by ordinary short connections having a total length of about 10 feet. Each story corresponds to a height of about 10 feet. Fall of temperature, 20°.

TABLE 19.

SIZE OF HOT-WATER RISERS.

Diameter of Riser. Inches.	Story Where Heater is Located.					
	1	2	3	4	5	6
$\frac{3}{4}$	12	17	21	24		
1	22	32	40	48		
$1\frac{1}{4}$	38	56	70	80	88	
$1\frac{1}{2}$	66	92	112	132	145	
2	140	196	238	280	310	
$2\frac{1}{2}$	240	328	400	470	515	
3	350	490	595	700	770	850
$3\frac{1}{2}$	510	705	860	1010	1110	1215
4	700	980	1190	1280	1540	1660

217. Size of Radiator Connections.—In the following table the area of radiator surface is given, which is adapted to connections having the diameter given, for service on the first floor, that is, at an elevation between 10 and 15 feet above the level of the return connection to the boiler. It is assumed that the aggregate length of the flow and return connections is about 10 feet, and also that they include six elbows, or their equivalents, the resistance offered by such connections to the flow of water being the same as that of 100 feet of plain, straight pipe. Fall of temperature, 20°.

TABLE 20.

DIAMETER OF RADIATOR CONNECTIONS.

Size of Pipe in Inches.	$\frac{3}{4}$	1	$1\frac{1}{4}$	$1\frac{1}{2}$	2	$2\frac{1}{2}$
Area of Direct Heating Surface in Square Feet.	16	24	40	60	120	240

If the area of heating surface exceeds the amount given, the fall of temperature will exceed 20°, and if it be less, the fall will be less correspondingly. If the connections are long or crooked, less heating surface can be operated, or a larger drop in temperature will occur.

218. In order to find the proper sizes of pipes for indirect-heating apparatus by means of the tables given, it is necessary to convert the area of indirect-heating surface into an equivalent area of direct-heating surface. This should be done by adding 50 per cent. to the actual area of the indirect radiators.

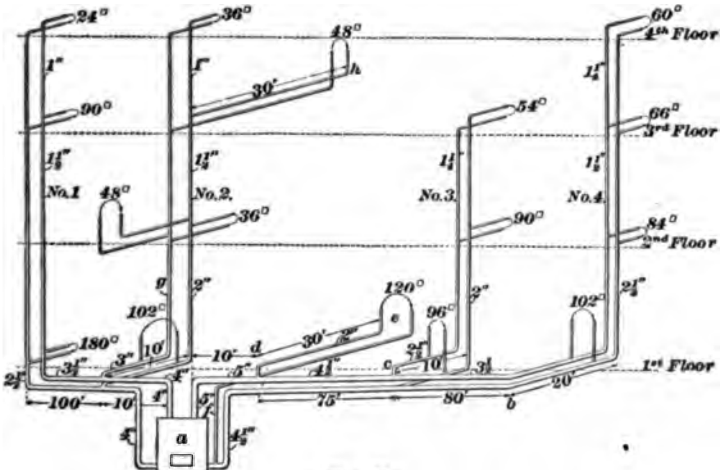


FIG. 80.

219. The manner of determining the proper sizes of the various parts of a hot-water pipe system by means of the foregoing tables will be explained by the aid of Fig. 80. This is a diagram showing the area of heating surface required at each radiator, the height of the various risers, and the length of the horizontal branches and mains. The vertical lines represent risers, the horizontal lines represent mains, and the oblique lines indicate horizontal branches extending at right angles from the pipes to which they are attached. The horizontal dotted lines indicate the several floor levels. The figures having the symbol □ attached to them (thus, *60*□) indicate the area in square feet of the radiator at that branch. The risers are numbered *No. 1*, *No. 2*, etc., for convenience in reference. The length of each horizontal branch is noted in feet, and the lengths of the several parts of the mains are also noted.

220. Having a suitable working drawing, the work of computing the diameters of pipes should begin at the point most remote from the boiler, which, in this case, is the radiator on the 4th floor on riser *No. 4*.

The riser must supply water sufficient for 60 square feet of heating surface at that point. Referring to Table 19, it appears that on the 4th floor a 1-inch pipe is best adapted to 48 square feet, while a 1¼-inch pipe will serve 80 square feet. If the 1-inch pipe is used, the fall of temperature at the radiator will be more than 20°; therefore, it is wise to use the 1¼-inch pipe.

The pipe leading from the 2d to the 3d floor must supply the 60-foot radiator on the 4th floor and also the 66-foot radiator on the 3d floor—a total of 126 square feet. The table shows that 126 feet on the 3d floor will be nearly supplied by 1½-inch pipe, while the next size, 2-inch, is much too large. If there were no radiator on the 2d floor, it would be advisable to use the 2-inch pipe from the 66-foot radiator down to the mains.

The riser from the main to the 2d floor must supply three radiators, aggregating 210 square feet. The table shows that 2-inch pipe is a little small, while 2½-inch is larger than necessary. But it should be noted that there are elbows at the foot of these pipes; therefore, it is wise to use the 2½-inch diameter.

The sizes of the other risers should be determined in a similar manner. The horizontal lines may then be considered. That part of the mains extending from *No. 4* riser to the connections to *No. 3* must supply a first-story radiator in addition to *No. 4* riser, aggregating 312 square feet. The length of the flow pipe is 100 feet, which, added to the same length of return pipe, makes a circuit of 200 feet. Referring to Table 18, it appears that 312 square feet of surface, on a 200-foot circuit, requires a 3½-inch pipe. This size is a little larger than that actually required, and will compensate for the elbows at *b*.

At the point *c* another circuit is attached, *No. 3*, which supplies 240 square feet of heating surface, making the total surface to be supplied at that point $240 + 312 = 552$ square feet. The distance between the points *c* and *d* is 75 feet, making the circuit 150 feet long. The table shows that

552 square feet of surface, on a 200-foot circuit, requires a $4\frac{1}{2}$-inch pipe. The return may be continued to the boiler with that size, but the flow main should be enlarged at *d* to provide for the radiator at *e*.

The length of the connections to this radiator is so much greater than ordinary that the circuit should be considered as a 100-foot circuit. The table shows that 120 square feet of surface requires 2-inch pipes.

It will be noted that this radiator is also provided with an independent return connection, as shown at *f*. This construction insures a good circulation, more positive and rapid than if the return were connected into the return main at *d*. The difference is owing to the length of the horizontal branches. If the radiator were located close to the mains, there would be no considerable advantage in providing it with an independent return.

The circulation in circuit *No. 2* would probably be improved by providing the return pipe *g* with an independent connection to the boiler, instead of connecting it into the return main, as shown in the drawing.

The radiator *h*, on circuit *No. 2*, has long connections. It is explained in Art. **211** that a given size of pipe will supply 1.7 times as much heating surface on the third floor as on the first; therefore, this radiator corresponds to one on the first floor having $48 \div 1.7 = 28$ square feet of surface. Table 18 shows that a radiator of that size on a 100-foot circuit requires $1\frac{1}{4}$-inch pipes.

HEATING GREENHOUSES.

221. Greenhouses may be heated satisfactorily with either steam or hot water, but the latter is generally preferred, because of the simplicity of the apparatus, and its ability, when properly arranged, to store up large quantities of heat. The apparatus is made to contain an amount of water that is very large in proportion to the cooling surfaces of the greenhouse, thus constituting a reservoir of heat. If the fires burn low or go out, the stored heat is

given out gradually and serves to keep the temperature from falling too rapidly, thus protecting the plants from damage until the fires are attended to.

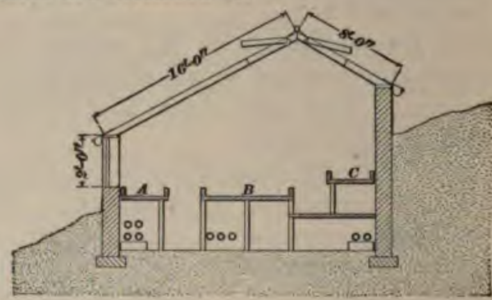


FIG. 81.

222. Figs. 81 and 82 show a greenhouse which is supposed to be located on the side of a hill. It is constructed with two or three large parallel benches or platforms, A, B, C, which run the whole length of the building, for the

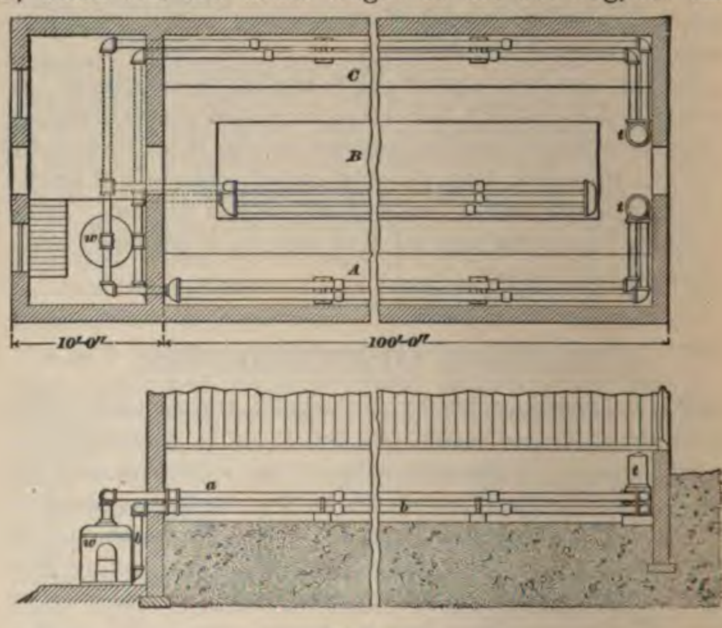


FIG. 82.

purpose of holding plants that grow in pots; or, they may contain a bed of earth or sand in which seeds and cuttings are propagated. The outside or wall benches should have a space about 2 or 3 inches wide made between the bench and the wall, so that the warm air rising from the heating pipes will pass upwards in a sheet, as it were, in front of the windows, and thus neutralize the downward current of cold air which would otherwise exist at that point.

It is necessary to control the temperature at each bench, in order to grow plants to the best advantage; therefore, each set of pipes must be provided with suitable controlling valves.

The pipes commonly used for hot-water service in greenhouses are made of cast iron and are slightly less than 4 inches in diameter, 1 lineal foot of pipe being equal to 1 square foot of heating surface.

223. The following ratios of heating surface to glass surface have been found in practice to give good results, and may be used in designing hot-water heating systems for greenhouses. The external temperature is supposed to be 0° F., the exposure of the greenhouse moderate, and the construction good.

TABLE 21.

PROPORTION OF GLASS TO HEATING SURFACE.

	Steam.	Hot Water.
For 45° inside temperature, divide glass surface by	8	5
For 50° inside temperature, divide glass surface by	7	.5
For 55° inside temperature, divide glass surface by	6.5	4
For 60° inside temperature, divide glass surface by	6	3.5
For 65° inside temperature, divide glass surface by	5	3.25
For 70° inside temperature, divide glass surface by	4.5	3

224. Arrangement of Pipes.—The pipes are usually laid in long parallel lines, under the benches, as shown in Figs. 81 and 82, with one or two flow pipes *a* resting on top of two or three return pipes *b*. They are supported at intervals by brick piers, at a sufficient height above the floor to secure a good supply of air to the inside of the group of pipes. They are all laid upon an upward grade from the boiler to the farther end of the line.

The **head** available in greenhouse apparatus is seldom more than 6 feet, and is usually much less. As the buildings are frequently from 300 to 400 feet long, it is evident that the grading of the pipes must be carefully done. In order to secure as much head as possible, the boiler should be set in a pit or cellar.

225. The **expansion tank** is usually placed at the end of the line of pipe most remote from the boiler. Each line or group of pipes may be provided with an expansion tank, or one large tank may be used for the whole system. Both the flow and return pipes are connected to the tank, which thus serves as a return connection and as a vent for air. The top is closed by a loosely fitting cover.

In the plan view, Fig. 82, the pipes shown under the side tables are provided with separate tanks *t*, while the middle line has none. As it may be inconvenient to place a tank at the end of the middle table, it is therefore omitted in the drawing. These pipes are relieved of air by means of a $\frac{1}{4}$-inch or $\frac{1}{2}$-inch pipe, which is tapped into the highest point, and is extended upwards above the level of the top of the expansion tanks. The boiler *w* is set in a pit, as shown in the side elevation.

Rust joints are used instead of lead-calked joints for cast-iron heating pipes. The cement is made by mixing 100 parts, by weight, of iron filings or borings, pounded fine, with from 1 to 2 parts of sal ammoniac, enough water being added to make the mixture into a thick mortar.

The bottom of the socket is closed by calking in a strand

of oakum in the usual manner, and then the remaining space is filled with the cement and lightly calked. The sal ammoniac attacks the iron and rapidly converts it into rust, which hardens into a dense, tough mass, and clings to the iron pipe with great tenacity.

FURNACE HEATING.

HOT-AIR FURNACES.

DESCRIPTION OF FURNACES.

226. A hot-air furnace may be described as a device for heating a continuous current of air by means of a fire contained within the apparatus and without mingling the fresh air with the products of combustion.

It combines the functions of a heat generator with those of a radiator, and operates without the aid of any intermediate heat-carrying agent. The transmission of heat is direct, through a single plate or sheet of metal, from the fire or hot gas on one side to the fresh air on the other.

It is evident, therefore, that, in order to operate effectively, the construction of a hot-air furnace must conform to the laws which govern the absorption of heat from hot gases, and also to those which control the emission of heat from hot surfaces. Many of the varieties of hot-air furnaces now upon the market are built with little regard to these laws, and consequently have a very low degree of efficiency.

Many forms of furnaces seem to have been designed upon the theory that the air can be heated sufficiently by bringing it within the range of the radiant heat, which is emitted from the fire-pot and other hot parts, and that the actual *area* of the heating surfaces presented to the air is a matter of minor importance. Nothing could be further from the truth. The radiated heat is useless unless it is intercepted and absorbed by some surface which will impart it to the

air by contact and conduction. Hence, the efficiency of a furnace depends in a great measure upon the area of the hot surfaces over which the air is passed.

227. Extent of Heating Surfaces.—The actual rate of transmission of heat to air is much slower than the transmission from steam to metal, or from metal to water; consequently, the proportion of heating surface to the amount of fuel burned should be much greater in a hot-air furnace than in a steam boiler. The proportion of heating surface to grate area in steam-heating boilers ranges between 20 and 45 to 1, averaging about 35 to 1. The ratio in the hot-air furnaces now in general use is nearly the same, but should be much larger. In order to obtain the best results the ratio should average about 50 to 1.

The heating surfaces in a hot-air furnace should be sufficiently extensive to cool the hot gases of combustion, before they pass into the chimney, to a point not more than 100° above the temperature of the heated air which is discharged into the warm-air pipes. Any greater excess of temperature is unnecessary and wasteful.

228. Arrangement of Heating Surfaces.—In general features the construction of a hot-air furnace should approximate that of a tubular or water-tube boiler. The hot gases upon the inside, and also the fresh air on the outside, should be divided into thin sheets or small streams, and should be conducted through tubular channels or narrow passageways, having large areas of hot surface in proportion to the volume of the current. The hot gases should impinge upon the heat-absorbing surfaces as nearly as possible at right angles, and the movement of the gases should be in a direction opposite to that of the air.

On account of the slowness of the transmission of heat, to or from air and gases, it is necessary that the channels through which they pass should have considerable length, so that while the currents move with proper velocity, plenty of time will be afforded for transferring the heat. A

momentary exposure of the air to a red-hot surface is far less effective than a prolonged exposure to surfaces having only a moderate temperature. *Time* is an important element in heating air.

229. Figs. 83 and 84 show a furnace which is designed for use in large buildings, such as shops, schools, churches, etc. In principle it resembles a tubular boiler, the hot gases being conveyed through the air chambers within tubes

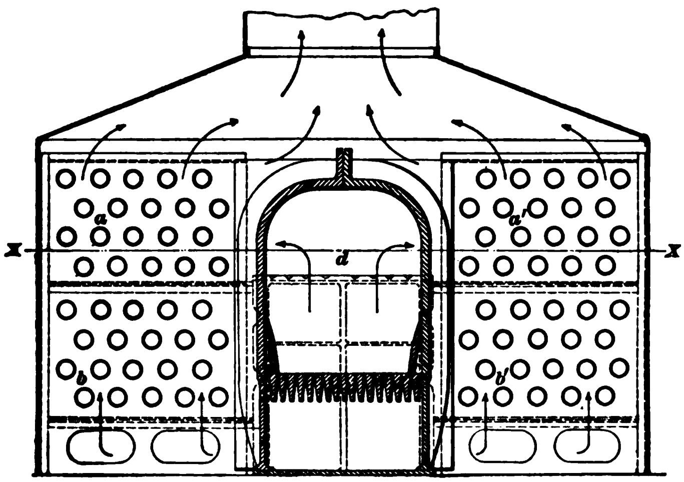


FIG. 83.

of comparatively small diameter. Fig. 83 is a vertical section parallel with the front, and Fig. 84 is a horizontal section on the line XX. The firebox is located in the middle of the structure and is surrounded by the air-heating chambers. The products of combustion pass to the rear, over the bridge wall d, and flow to the right and left into the combustion chambers l, l'. From these they pass through the upper sets of tubes a, a' into the front chambers n, n', and return through the lower tubes b, b' to flues at the rear, which conduct them to the chimney c. The air enters at the bottom of the casing, flows upwards between the tubes, and passes off at the top through the large central flue.

The tubes are secured to the tube-sheets in such a manner as to permit any tube to be readily removed by means of a common wrench when burned or clogged.

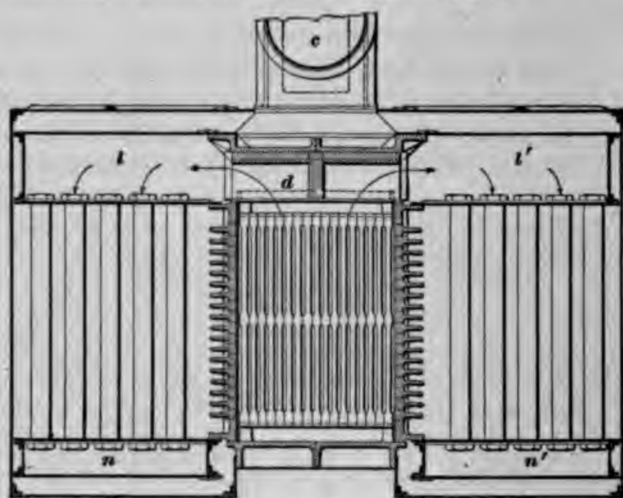


FIG. 84.

There are so many hot-air furnaces in the market that no attempt will be made to describe them in detail. Circulars and descriptions can easily be obtained upon application to manufacturers or their agents.

COMBINATION HEATERS.

230. These heaters are the same in construction as ordinary hot-air furnaces, except that they are provided with extra parts, which serve to heat water in sufficient quantity to supply a small number of radiators.

In making a selection of a combination heater, particular regard should be given to the construction of the hot-water heater. This is usually of small dimensions and is liable to have small contracted passageways, or small connections, which make it unfit for hot-water service. Any heater which requires that screwed pipe joints or fittings shall be exposed to the direct action of the fire should be avoided.

These water heaters may be divided into two classes: those which are exposed only to hot gases, and those which come into direct contact with the burning fuel. The latter class, when in operation, soon become separated from the live coal by a layer of ashes or dead coal; this hinders the transmission of heat and greatly diminishes the efficiency of the heater. The former class are free from this defect, but, on the other hand, some varieties are liable to have their usefulness impaired by accumulations of ashes and soot.

LOCATION OF A FURNACE.

231. The location of a furnace is governed principally by the situation or exposure of the house and the location of the chimney. In all the rooms upon those sides of the house which are exposed to the prevailing winds, the effect will be to make the temperature lower and the air pressure higher than in the other parts of the house. The increase of air pressure in these rooms makes it necessary that the hot air in the flues leading to them should have the highest practicable temperature and pressure, in order to flow into the rooms in sufficient quantity. These flues must, therefore, be connected to the furnace with the least possible length of horizontal piping, and, consequently, the proper place for the furnace is near the exposed, or coldest, sides of the house.

The work should be so planned that all long horizontal pipes will be connected only to the tallest vertical flues, and that only short ones will be employed to serve registers on the first floor. The furnace should be located as central as possible, with all due consideration for exposures.

FOUNDATIONS AND SETTINGS.

232. A hot-air furnace should be set at the lowest practicable level, so that even the longest horizontal hot-air pipe may be given a sufficient upward inclination to make it operate well. In some cases the ceiling of the basement is so

low that it is necessary to set the furnace in a pit. The extreme top of the furnace casing should never be less than 18 inches below the ceiling or floorbeams, and should be as much more as possible.

The side walls of the pit should be 8 inches thick if made of brick, and 12 inches or more if made of stone. The bottom should be covered with one course of brick on edge, or with concrete at least 4 inches deep, or, better still, with flagstones.

AIR SUPPLY AND DISTRIBUTION.

COLD-AIR SUPPLY.

233. The furnace should be supplied with fresh air by means of a duct, which has an inlet at some point above ground upon the windy side of the house. This inlet, or **cold-air box**, as it is often called, must always be upon that side of the house where the air pressure is highest—if it opens to the leeward side, the warm air in the furnace is very liable to be driven down through the cold-air flue and discharge out of doors.

If strong winds are likely to blow from various directions, then the cold-air duct should have inlets at the several exposed sides of the building. Each inlet must be provided with a damper, or other closing device, so that all may be shut off except the one which faces the wind.

Cold-air inlet openings should always be made high enough above the ground to prevent surface water from entering them, and they should be covered with wire netting to keep out animals, etc.

The common method of constructing a cold-air duct in the ground, which consists in building two small walls of brick along the sides of a trench having an earth bottom, and covering the trench with flagstones or planking, is a very bad one, and should not be permitted, unless the bottom of the trench is made water-tight. The worst arrangement, however, is a similar duct having wooden sides and top.

The wood slowly rots and the ground air freely enters the duct.

234. Underground ducts should always be strictly water-tight. A very good method of constructing such a duct is to use a terra-cotta pipe of sufficient size, cementing each joint as carefully as for a sewage drain. Fig. 85 shows a

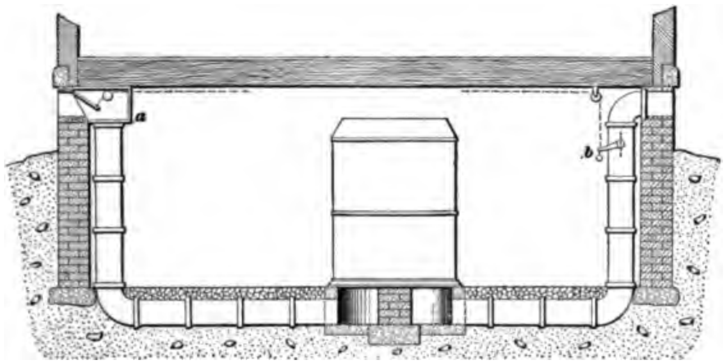


FIG. 85.

cold-air duct made in this way, with openings at opposite sides of the building. Two methods are shown of arranging the inlets and dampers. At *a*, the shutter, or damper, is hinged at one edge to the window frame; and at *b*, an ordinary butterfly damper is employed. These dampers may be operated from the rooms above, if so desired, by the use of chains and pulleys.

The **area** of a cold-air duct should equal $\frac{2}{3}$ or $\frac{3}{4}$ of the aggregate areas of all the hot-air pipes.

235. Inside Cold-Air Ducts.—In heating large rooms, the cold-air supply is sometimes taken through a register in the floor, as shown at *b* in Fig. 86. The air then circulates through the furnace and through the room continuously, without the introduction of any fresh air.

This method is useful only for heating the building, when ventilation is not required. It is used chiefly for warming a large space occupied by very few people. Or it may be

used for heating a large auditorium before the audience arrives, but as soon as ventilation is required a damper in the inside supply pipe is closed and that in the outside supply pipe *a* is opened.

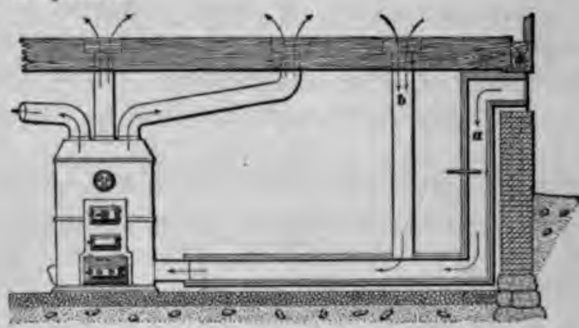


FIG. 86.

When this arrangement is used in private residence work, the inside supply register should be located in the front hall and near the front door, if possible.

HOT-AIR SUPPLY.

236. All hot-air pipes which convey the warm air from the bonnet of the furnace to the several rooms, should be run as straight as possible, and must all pitch up toward their outlets, which are protected by registers or gratings.

The choice of material for hot-air flues should be governed by considerations of durability and cost. They are commonly made of I C or I X bright tin.

All hot-air pipes should be covered with non-conducting material, in order to preserve the temperature of the hot air as long as possible, and thus secure the greatest possible draft. The vertical pipes which are built into the walls and partitions are usually called **stacks**. These are made flat or oval, to suit the spaces through which they must pass. In wooden buildings, a clear space of not less than ½ inch should be provided all around the pipe. This space should be packed with proper non-conducting material, or else the pipe should be wrapped with at least two layers of asbestos paper and

bound with wire. Stacks are sometimes made with double walls enclosing an air space between them; the air space is intended to prevent the escape of heat, and affords good protection against fire.

All hot-air pipes should be given an upward grade of not less than 1 inch per foot if practicable, and more if convenient. This grade is usually sufficient to overcome the friction of the air in the pipe and secure a reasonably good flow, provided that the temperature is not permitted to fall off during the transit.

237. Every leader should be provided with a **damper** at a point close to the furnace. The common butterfly damper is good enough for this purpose if carefully made and fitted.

238. Registers.—This name is commonly used to designate the special opening through which air enters or leaves a room, and it is also applied to the combination of valves and grating which is employed to control the opening.

A register consists of a group of valve plates or *louvres*, which turn on pivots at each end and are operated simultaneously by means of a link connection and a lever. They are supported in an iron frame and are protected by a stout iron grating or grille, which is made strong enough to be walked upon without injury. **Wall registers** are constructed in substantially the same manner.

239. The ordinary method of setting a floor register is to place it over the top of a tin **register box**, which is connected to the hot-air pipe by means of a collar at the bottom. As the sole purpose of the box is to connect the pipe to the register, it should be so designed as to offer the least practicable resistance to the flow of hot air.

SIZE OF PIPES.

240. It is common practice to proportion the area of a hot-air pipe to the cubical contents of the rooms which they supply. The area of the pipe in square inches may be found by the following rule:

Rule 12.—*For the first floor, divide the volume of the room in cubic feet by 30 for rooms having only a moderate exposure, or by 25 to 20 for rooms having great exposure.*

For second-floor rooms the divisor may range from 35 to 25, and for third-floor rooms, from 40 to 30.

241. A more accurate method is to proportion the area of the pipes to the cooling surfaces in the rooms. This may be done by the use of the following rule:

Rule 13.—*For rooms on the first floor, add together the total glass surface and $\frac{1}{4}$ of the area of the exposed walls in square feet, and multiply the total by 1.5; the product is the proper area of the pipe in square inches. For second-story rooms, multiply by 1 to 1.25, according to the exposure; and for the third story, by .75 to 1.*

242. The stacks, or wall flues, are usually flattened in form, and present more surface for friction than the leader pipes, which are usually round. When a stack is connected to a leader of considerable length, the area of the latter should exceed that of the former by 20 to 30 per cent., or even more in extreme cases.

In computing the size of a stack, some allowance must be made if its length in proportion to its area is unusually great. Allowance must also be made for all elbows and offsets.

If the quantity of air required per minute is known, the size of the pipe to carry it may be computed by dividing the required volume by the velocity of the air-current. In all ordinary cases the velocity of the air-current may be safely assumed at 4 feet *per second* at the first floor, 5 feet at the second floor, and 6 feet per second at the third floor.

Another method, equally good, is to reckon that *one square inch of stack, or flue, area will supply 100 cubic feet of air per hour at the first floor, 125 at the second, and 150 at the third floor.*

It is assumed in all of the foregoing rules that the average temperature of the hot air in the flues is about 120°, and that the air is moved solely by natural draft.

243. The following table shows the sizes allowed in common practice for pipes and registers in ordinary dwellings:

TABLE 22.

SIZE OF HOT-AIR PIPES AND REGISTERS.

First-Floor Rooms.				Second-Floor Rooms.			
Size of Register in Inches.	Diameter of Pipe in Inches.	Size of Rooms in Feet.	Height of Ceiling in Feet.	Size of Register in Inches.	Diameter of Pipe in Inches.	Size of Rooms in Feet.	Height of Ceiling in Feet.
12×15	12	16×16 to 18×20	11	10×14	10	16×16 to 18×20	10
10×12 or 10×14	10	14×14 to 15×15	10	9×12	9	14×14 to 16×16	9
9×12	9	12×12 to 14×15	9	8×12	8	10×10 to 13×14	8
8×12	8	8×12 to 13×13	9	8×10	7	7×12 to 12×12	8

SIZE OF FURNACE REQUIRED.

244. In order to estimate the proper size of a furnace for warming any given building, the first proceeding is to compute the probable loss of heat by radiation and conduction from the whole building, in heat units per hour, with the weather at zero, taking into consideration the situation and exposure to wind. The loss by ventilation must be added to the loss by cooling. (See Arts. **95-99.**) Where no definite ventilation system is employed, as in ordinary dwellings, the total loss from both causes may be computed by multiplying the estimated loss from cooling, in heat units per hour, by 2.18.

This is based upon the assumption that the hot air enters the room at 120°, and that all of it escapes at a temperature of 65°. Then it is plain that $\frac{65}{120}$ of the total heat (above 0° F.) supplied by the hot-air current is lost, and that only $\frac{55}{120}$ is expended in maintaining the temperature of the room. The heat lost by ventilation in that case is $\frac{65}{55}$, or 118 per cent. of the loss by cooling, and the total loss is thus 218 per cent., or 2.18 times the estimated loss by radiation and conduction.

The next step is to compute the amount of fuel that must be consumed per hour. This may be found by dividing the total estimated loss of heat per hour, by the number of heat units that will be given off by each pound of the fuel in burning.

The furnace, however, will not transfer all the heat developed by the fuel to the air passing through, but will waste a large portion of it. The coefficient of efficiency of hot-air furnaces ranges from 50 to 60 per cent.; therefore, the estimate of fuel required must be increased 66 to 100 per cent. accordingly.

The rate of combustion per hour in ordinary furnaces averages about 3 pounds of coal per square foot of grate surface. The required grate area in square feet may be found by dividing the proposed fuel consumption in pounds per hour by 3. Thus we arrive at the dimension upon which all others depend—that is, the *area of the grate*.

The area of the heating surfaces should be from 40 to 50 times that of the grate, as previously explained.

245. When heat is required at a greater distance than 30 feet, it is advisable to use a **combination furnace,** and employ steam or hot-water radiators at the remote points. Radiators may also be used to good advantage in corridors and vestibules, where outside doors are frequently opened and where it is difficult to retain warm air.

In large jobs requiring great quantities of hot air, it is customary to employ several furnaces set singly or in groups. In many cases it is better practice to use a number of inde-

pendent furnaces, instead of one large furnace, or a group of furnaces centrally located. Each single furnace may then be located in a position which will enable it to serve, to the best advantage, the section of the building assigned to it.

The use of independent furnaces involves more labor on the part of the attendant, but in such cases it is better to provide the extra labor than to sacrifice the efficiency of the heating system, and permit it to fail when heat is most needed.

VENTILATION.

INTRODUCTORY.

246. The primary object of ventilation is the *removal* of the vitiated air. This being done, natural air, presumably of better quality, will flow in from all directions to take its place. The preparation of this fresh air for use by warming and otherwise, is a secondary matter, although one of great importance.

The need of heat for warming purposes is universally understood, but the necessity of having pure air to breathe is not so well known; indeed, many people, otherwise well informed, regard the demand for pure air as an unnecessary refinement. It may be noted, however, that people can endure great variations in the temperature without injury, merely by adjusting the amount of their clothing, but that they cannot breathe foul air without paying the full penalty in every case, and that there is no possible way of adjusting the human organism so as to be unharmed by it.

The evil effects of the habitual breathing of vitiated air, by both men and animals, have been carefully observed for long periods of time. The most noticeable and certain effect is the lowering of the vital energies of persons thus exposed, producing what is called "general debility," and making them very susceptible to disease in all forms. Healthy

people possess a high resisting power against disease, but the continued inhalation of impure air constantly diminishes this power of resistance, until the persons thus affected easily succumb to any adverse influence that may be brought to bear upon them. Children have less vital energy than adults, and are more quickly and seriously affected.

Good ventilation is not only desirable for the pleasure which is afforded by breathing fresh, invigorating air, but is also absolutely necessary for the maintenance of good health, and to prevent the spread of infectious diseases. It is highly desirable, also, as a matter of cleanliness.

THE VITIATION OF AIR.

247. Air is rendered unfit for breathing by a great variety of causes, that of respiration being the most conspicuous.

Each adult person breathes about 20 times per minute and inhales about 30 cubic inches of air at each breath. The air on entering the lungs contains about 79 per cent., by volume, of nitrogen, and 20.8 per cent. of oxygen, with a very small fraction of carbonic acid; but when it is expired it contains only about 15.4 per cent. of oxygen, while the carbonic acid is increased to about 4.3 per cent. of the total volume. The quantity of available oxygen is thus reduced from 20.8 parts to 15.4 parts, or very nearly 26 per cent.

Oxygen is the only part of the air (excepting the moisture) which serves to sustain life. The nitrogen is wholly useless, being perfectly inert, and is expelled from the lungs without undergoing any change whatever. It is inhaled simply because it is so thoroughly mixed with the oxygen that its inhalation cannot be avoided. Only about 21 per cent. of the air is of any use for sustaining life; the remainder merely acts in a mechanical way to dilute the oxygen and increase the volume of the mixture. Air which is breathed once thereby loses 26. per cent. of its oxygen, that is, 26 per cent. of its total life-sustaining power.

248. The amount of oxygen consumed per hour varies with the age and state of health of the person, and also with the degree of activity—whether asleep or awake, or engaged in muscular labor. Animals require more oxygen than men.

The amounts of oxygen consumed in equal times, per pound of actual weight (not per head), are in the following proportions:

Man,	100.	Sheep,	117.	Dog,	283.
Horse,	135.	Ox,	132.	Chicken,	312.

The average adult man consumes oxygen at the rate of 20 cubic feet per day, or about 1 cubic foot per hour while engaged in active labor, and less when quiet or asleep.

249. The formation of carbonic acid in the lungs is practically continuous, only a portion being expelled at each breath. The oxygen which is absorbed into the lung cells comes into contact with carbonaceous matter derived from the food, and combination takes place, resulting in the formation of **carbon dioxide,** commonly called carbonic acid, (symbol CO_2). This process, in fact, is one of combustion, and is in every respect the same as that which takes place in a furnace, except that it is less intense. The carbon is supplied at a rate which maintains the temperature at about 98° F. The amount of CO_2 which is thus produced in 24 hours averages about $16\frac{1}{4}$ cubic feet for each adult person. Children produce a little less, and sick people often considerably more. The rate of production varies from hour to hour, being commensurate with the muscular activity of the individual.

If this carbonic-acid gas is not contaminated with anything else, air containing $1\frac{1}{2}$ per cent. of it may be breathed for an hour or more without harm, but in most cases it is accompanied by other poisonous compounds, which make one-tenth of that proportion hardly endurable.

250. Organic Impurities.—The interior surfaces of the lungs, and the whole exterior surface of the body, exhale moisture continually, although at varying rates. Certain

other substances, more or less volatile, are exhaled at the same time. These have a rank odor, especially when abundant, and they decompose very readily, giving rise to odors still more offensive. This class of emanations appear to have a positively toxic or poisonous effect upon those who inhale them. The exact chemical composition of these substances is difficult to determine, but long continued and careful experiments have made it certain that they cause great discomfort and a feeling of oppression, when present in the air in moderate quantities, and that when concentrated they are dangerous.

The quantity of organic substances thus exhaled appears to bear a definite proportion to the amount of carbonic acid produced by respiration in the same time. The ratio is found to be so nearly constant that the percentage of the latter may be safely taken as an index of the quantity of the former existing in the air from the same cause.

There is another large class of organic emanations which pollute the air of dwellings and assembly rooms. These proceed from the *bodies* of persons who are troubled with indigestion and various gastric and intestinal disorders.

251. The **dust** found in the air of dwellings, etc., is composed mainly of small fibers derived from the wear and tear of cloth and wood, and minute fragments of various kinds of stone. In thickly populated districts it is likely to contain also soot and the dried remains of decaying vegetable matter. Such dust is, as a rule, comparatively harmless, merely irritating the nostrils and lungs, but doing no positive injury unless it is present in large quantities.

But the dust from wagon roads and paved streets is much filthier in character. A considerable percentage of it consists of finely pulverized horse dung, and in the vicinity of streets paved with stone or asphaltum the greater part of the dust is found to consist of this unsavory material. Wooden pavements are still worse, because they absorb and store up the liquid excreta dropped upon them, giving it off again as dust when dried, and as a most loathsome vapor when wetted by

summer showers. Of course such dust as this must be excluded from the lungs at any cost.

252. There is another ingredient occasionally found in dust which deserves close attention, that is, the germs of putrefaction and contagious diseases. These are microscopic plants which attach themselves to the dust particles and are borne around by them. They are called by the general name of **bacteria.** They are very diverse in appearance, and also in the effects produced by their lodgment and growth. They may be divided into two great classes: those which flourish only upon dead matter, animal or vegetable, and those which thrive only upon living animals or plants, and exist at their expense.

The former class are called *saprophytes*—that is, destroyers of dead things. They break up putrescible matter and reduce it to carbonic acid, ammonia, and other simple compounds, suitable for the immediate use of ordinary growing plants.

The other class of bacteria are true *parasites*. These are the dangerous ones. When one of them alights upon a living creature, upon a part which is both moist and warm, it begins at once to increase and multiply, some kinds slowly, and others with great rapidity. They not only rob the system by absorbing some of the fluids which should nourish the body, but they also produce virulent poisons which derange the system in various ways.

253. Ground Air.—Ordinary soil, which is capable of supporting grass or producing a crop of vegetables, is in reality an extensive manufactory of gas. It is here that the myriads of saprophytes, already described, perform their work of decomposing all animal and vegetable remains into elementary substances suitable for the nutriment of living plants. The result of their operation is to produce large quantities of carbonic acid, together with various ammonia compounds, and, occasionally, sulphureted hydrogen. Free ammonia, however, occurs only in very small proportions.

Carbonic acid is also produced by the chemical interactions

taking place between the mineral substances contained in the soil, the amount varying with the nature of the materials and the degree of moisture.

The production of gas is most copious in soil of moderate moisture; very dry earth produces but little. When the soil is constantly saturated with water, the processes are different, and the quantity of gas evolved is usually smaller.

254. Any excavation in the earth, such as a cellar, trench, or well, acts as a vent for the gases contained in the adjacent soil.

Ordinary cellars act as collecting basins for these earth gases; and, unless adequate ventilation is provided, they will pass up through the floor and diffuse into the rooms above. The inflow of gas cannot be stopped by facing the walls or bottom with Portland cement, because gases will pass through ordinary brick, mortar, and cement, about as readily as water will percolate through a stratum of fine sand. The cement will serve to retard the flow somewhat; but, in order to stop it, substances like asphaltum or paraffin must be used.

AMOUNT OF AIR REQUIRED.

255. There is only one way by which the fitness of air for respiration can be determined with any certainty, and that is by chemical examination. The sense of smell cannot be depended on for this purpose, because it is so easily blunted. After remaining in a room full of bad air for 10 or 15 minutes a person will usually be unable to perceive any unpleasant odor about it. It is only upon passing from the fresh outdoor air into a tainted atmosphere that the sense of smell can be relied upon to discover the bad quality of the air, but even then no accurate estimate can be made of the real degree of pollution.

When the carbonic acid gas due to respiration and exhalation does not exceed 2 parts in 10,000, the air is considered fresh and wholesome. When a definite animal or musty odor begins to be perceptible, the air is said to be *rather*

close, and the exhaled carbonic acid gas is found to amount to 4 or 5 parts. When the proportion increases to 7 or 8 parts, the air is called *close* or *very close*, and when it reaches 12 parts in 10,000 the air is pronounced *very bad*. Above this point the sense of smell fails to perceive any marked difference.

256. Proper ventilation requires that the exhaled carbonic-acid gas should not, at any time, exceed 2 parts in 10,000. The amount of air that will be required, per minute, to maintain this degree of freshness may be readily computed.

Each adult person in good health breathes out about .7 of a cubic foot of carbonic acid per hour, and in the same time exhales from the lungs and skin about .091 pound of water, which at 70° becomes about 80 cubic feet of steam or vapor. He also imparts about 400 heat units per hour to the air of the room by conduction and radiation from his body. The air supplied for ventilation must, therefore, serve three purposes: to dilute the carbonic acid to a proper degree; to absorb the vapors exhaled, without permitting any noticeable increase in the humidity; and to absorb the heat as rapidly as emitted, without perceptible rise of temperature.

In order to dilute .7 of a cubic foot of carbonic acid to the proportion of 2 parts in 10,000, it is necessary to mix it with $\frac{10,000 \times .7}{2} = 3,500$ cubic feet of air. Therefore, the air supply should be 3,500 cubic feet per hour for each adult person, or nearly 1 cubic foot per second. Taking into consideration the smaller amount of carbonic acid produced by children, the supply for schoolrooms and similar places may be reckoned at 3,000 cubic feet per person, per hour.

257. The volume of the air supply required varies with the season and the condition of the outer atmosphere. In clear, cold weather, 3,000 cubic feet per hour per head is sufficient for good ventilation; but on a mild spring day, with a damp, muggy atmosphere, it is difficult to get enough air without getting too much heat at the same time. ***The air is not dried*** in the least by passing through heaters, and is so

moist and warm that it fails to remove the animal heat as fast as necessary. Where people are assembled in considerable numbers, as in schools, etc., it is likely to produce feelings of great lassitude, and even fainting spells. On such occasions as these, it is highly desirable to have some means for reducing the humidity of the air.

258. *Cubic space* is not an important factor in ventilation, but there is a certain *minimum space* required for each person which must never be disregarded. The carbonic acid and other exhalations from the body diffuse themselves through the air with comparative slowness, and in order to secure their dispersion into the atmosphere with proper rapidity, it is necessary that every person should have a certain amount of "breathing room."

The minimum space that may be permitted, in cubic feet per person, is as follows:

In a lodging or tenement house	300 cubic feet.
In a schoolroom	250 cubic feet.
Barracks	600 cubic feet.
Ordinary hospital ward	1,000 cubic feet.
Fever or surgical ward	1,400 cubic feet.

Floor space must be considered as much as mere cubic space. Thus, in a schoolroom, there must be an aggregate of 25 square feet of floor surface for each pupil; and in hospitals each bed must have 100 square feet of space.

In stables, each horse or cow should have 100 square feet of floor space. A horse should have 1,600 cubic feet of air space, and a cow not less than 1,200. As cows are usually kept to furnish milk for food, it is important that they should be kept in a healthy condition, and that the air around them should be clean. The practice of furnishing their quarters with plenty of good air has been found highly beneficial.

PREPARATION OF AIR.

259. In many cases the air supplied to public halls and other large buildings requires to be treated in various ways, to render it wholesome and prepare it for personal use with

comfort. In summer time, it needs to be washed free from dust, and also to be dried and cooled. During the winter months, it is necessary not only to heat the air, but to increase its humidity also.

MOISTENING AIR.

260. The proper degree of humidity of a fresh-air supply varies in different countries. In the United States, the **dew point** of the air when delivered into rooms should be about 40° F. This gives about 40 per cent. of humidity when the air has a temperature of 70° F.

Thus, if the air is fully saturated with moisture when at a temperature of 40°, its humidity will be correct when it reaches the temperature of 70°, no matter how much it may have been heated in the meantime. It is seldom necessary to raise the dew point any higher, except for certain manufacturing purposes, such as in weaving rooms, etc.

261. The methods commonly used for moistening air consist in passing it through a spray of water, or over the surface of water contained in evaporating pans, or by injecting steam into the air-current.

A very convenient method of humidifying a current of air is to inject steam into it. The jet should blow at right angles to the direction of the current, so that the steam will diffuse readily throughout the whole mass of air. The orifices usually required are very small, but they should never be made less than $\frac{1}{32}$ inch in diameter, because such fine holes are very liable to become clogged and cease to operate.

The weight of steam that will be discharged into the atmosphere, per hour, through jets of small diameter, the pressure being not lower than about 20 pounds per square inch, absolute, is found to be as follows:

Orifice $\frac{1}{32}$ inch diameter = .03944 pound,
Orifice $\frac{1}{16}$ inch diameter = .15770 pound,

for each pound of steam pressure.

At lower pressures, the rate of discharge becomes slower and cannot be conveniently computed.

DRYING AND COOLING AIR.

262. The process of drying air is just the reverse of that for drying cloth and other wet materials.

In the ordinary process of drying, the materials are heated, in order to convert the moisture into steam and drive it off into the atmosphere; but in dealing with humid air, the only way by which the moisture can be reduced is by condensing a part of it.

Air cannot possibly be dried by heating it; on the contrary, if hot air encounters any water, it will impart heat to it and cause more evaporation, thus actually increasing the amount of vapor per cubic foot of space. The only practicable method, therefore, of drying air, that is, of condensing the atmospheric steam, is to lower its temperature.

263. The method usually adopted for this purpose is to pass the air over trays containing ice, or over pipe coils containing cold brine or other refrigerating liquids. It has been attempted in many cases to perform the work with coils which were filled with water at ordinary natural temperature, but the results were not entirely satisfactory.

An apparatus that employs natural water in the coils is useful for cooling purposes only: it is quite incapable of drying ordinary air, because the water seldom has a temperature in summer time of less than 55° or 60°, and, consequently, cannot lower the dew point below 60°. The humidity of air at 70°, having its dew point at 60°, would be about 71 per cent., which is far too high to be comfortable. In this respect, such apparatus is quite inferior to that in which ice or cold refrigerating liquids are employed.

FILTERING AIR.

264. The object of filtration is to arrest dust, smoke, etc., and prevent it from passing into the building. The apparatus employed is of two classes: wet and dry.

A **wet filter** consists of a coarse netting, which is stretched across the airway and is kept constantly wet or moist. The

net may be made of small rope or other rough fiber, and should have a mesh not larger than 1 inch. The water should be allowed to trickle down over it constantly, keeping it wet enough to make the dust adhere wherever it touches. The net gradually becomes loaded with dirt, which requires to be washed off. This may be done automatically by means of an ordinary periodical flushing tank, arranged to empty a liberal supply of water over the screen.

265. A **dry screen** for a large airway may be constructed as shown in Fig. 87. A set of inclined screens *a, a* are supported upon transverse bars *b* and *c*. These screens are made of wire netting, having a mesh of 2 inches or

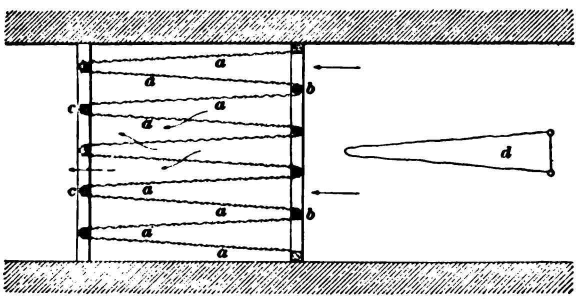


FIG. 87.

more; and their purpose is to support other screens made of cheese cloth or light muslin. They are fixed in place, and do not need to be removed for cleaning.

The cloth filters are made in the form of V-shaped bags, as shown at *d*. They are secured in place by fastening the front edges to the bars *b*; the air entering at the open mouth inflates them so that they lie tightly against the wire screens *a*. The total area of filtering surface thus exposed should be 8 to 10 times the sectional area of the airway. The filter bags must be removed at intervals and emptied of dust, and they should also be thoroughly washed and dried before they are used again.

DIFFUSION AND DISTRIBUTION OF AIR.

266. It may easily happen that the ventilation of a room will be very unsatisfactory, notwithstanding that a current of fresh air of sufficient quantity is constantly passing into and out of the apartment. Unless the incoming air is introduced in a proper manner, it may pass in a nearly unbroken current from the inlet to the outlet, and practically fail to disturb and renew the main body of air in the room.

Good ventilation requires that the foul air shall be well mixed and diluted with that which is pure; but whether the desired mixing will take place or not depends mainly upon the care and skill employed to insure the conditions necessary for proper diffusion. Neglect at this point has led to many serious failures in ventilating buildings. Diffusion proceeds best when the whole body of air is at a uniform temperature.

In still, cold air, the products of respiration, being warm, ascend at a rate slightly greater than the rate of diffusion; consequently, there is sometimes a little more carbonic acid, etc., to be found near the ceiling than near the floor, but, as a rule, it is uniformly distributed throughout the space.

267. If warm, fresh air is introduced near the top of a room it will lie against the ceiling in a body, and will not diffuse to any satisfactory extent into the colder air below. To get it down to the breathing level, it must be driven down by force; there is no other way.

The tendency of ascending currents of hot air is to flow in well defined streaks, the separation becoming more marked as the difference in temperature increases. The diffusion may be greatly improved by introducing the hot air in a large number of small streams, but this is impracticable in many cases on account of the expense involved.

268. Adhesion of Currents to Surfaces.—Another important property of air-currents, both hot and cold, which is of great importance in the art of ventilation, is their

tendency to adhere to surfaces along which they happen to be moving. For instance, if a current flows horizontally through an opening at the level of the floor, it will keep close to the floor and be plainly perceptible a long distance away; but a similar current issuing from an opening in the wall, midway between the floor and ceiling, would be quite imperceptible at only a few feet in front of the register.

In a similar manner, a current of cold air formed by the cooling action of a large window will, in many cases, descend and creep along the floor almost to the opposite side of the room before it diffuses, making it very uncomfortable around the feet and ankles of the occupants. In this way, annoying drafts may occur at points where they are least expected.

ACOUSTIC EFFECTS OF AIR-CURRENTS.

269. It is a matter of great importance in all public buildings, such as churches, theaters, lecture rooms, etc., that a person speaking from the stage or platform should be distinctly heard at any point on the floor or in the galleries.

The transmission of sound is affected to a considerable degree by currents in the air, and by variations in its density, or temperature. If a sound projected by the speaker encounters an air-current, it will be deflected from its original course, and will appear to the hearer to be somewhat weaker than it otherwise would. If a number of currents are encountered, the weakening effect will be very noticeable.

The greatest obstruction, however, is caused by inequalities in the temperature of the air through which the sound passes. Sound is always retarded by passing from a denser medium into a lighter one, and *vice versa*. When an audience room is full of streaks of warm air, either ascending or descending, the voice of the speaker will be so retarded in passing through them successively, that persons in the remoter parts of the room will have great difficulty in hearing plainly.

For these reasons the practice of introducing the warm

air through large openings in the vertical front of the stage, or through large floor registers between the audience and the speaker's platform, is a bad one, and should be carefully avoided.

VENTILATION SYSTEMS.

UPWARD AND DOWNWARD VENTILATION.

270. The comparative advantages of these opposing systems of ventilation may be briefly stated as follows:

1. The currents of warm air arising from human beings and containing the exhalations and products of respiration are warmer than the surrounding air, and naturally tend to move upwards. Thus they tend to assist upward ventilation and to impede downward movement. The amount of force required to overcome the rising tendency of these currents is so small, however, that it need not be considered in cases where fans are used for forcing the air, nor, in fact, in any case, except where ventilating chimneys having comparatively weak draft are employed.

2. The hot air and gases produced by gas burners, etc., have a strong upward tendency, and in some cases may be a valuable auxiliary to upward ventilation. When the downward system is used, these lights should be enclosed, and the products of combustion carried away to avoid contaminating the fresh air. Usually these hot gases can be utilized to increase the draft, by discharging them into the foul-air flues.

3. The direction of the ventilating movement has only a very slight effect in varying the distribution of the exhalations and products of respiration throughout the room. The tendency which these have to float upwards is counteracted in the downward system by the general movement of the air, and they are swept down to the floor and into the outlet flues. In the upward system, they are merely carried in the opposite direction. The quality of the air at the breathing level depends mainly upon the proportion of fresh air supplied.

4. In rooms that are likely to be fully occupied, it is difficult to locate the fresh-air openings in or near the floor so that the incoming currents will not impinge on some part of the bodies of the occupants and produce disagreeable sensations. The difficulty is aggravated by the tendency of air-currents to adhere to the surfaces, both vertical and horizontal.

In downward ventilation, the incoming currents are likely to be dissipated before they reach the lower part of the room, and consequently they may be comparatively few in number and larger in volume, and may have a higher velocity. The foul air may, without producing uncomfortable feelings, be taken out through floor openings at a higher velocity than could be allowed for inflowing currents.

5. The ascending air-currents employed in the upward system tend to carry up into the breathing zone the dust and other offensive matters which otherwise would lie upon the floor. As the upward flow is continuous, the dust is kept in constant circulation, and no opportunity is given it to settle. Downward currents, on the contrary, will carry it directly into the outlets and thus dispose of it.

6. In audience rooms of great height, having balconies and galleries, either system may be applied successfully, so far as the distribution of fresh air and heat is concerned, but the acoustic properties are likely to be better with the downward system, because the main body of air is more likely to be uniform in density and temperature, and free from perceptible currents.

THE EXHAUST AND PRESSURE SYSTEMS.

271. Air may be moved and distributed with equal facility by either of these systems, provided that the difference in pressure, above or below the atmosphere, is the same, and that the apparatus is of equal capacity. But the leakage of air which takes place through every hole and crevice in the walls, and around every loose-fitting window, etc., affects the exhaust system far more seriously than the other. When air is drawn through a heating apparatus consisting of a

hot-air furnace, some of the products of combustion are certain to leak through the furnace joints and poison the air supply. With the pressure system, no leakage of gas is likely to occur. On the contrary, the fresh air is likely to force its way into the interior of the furnace.

The practical difference between the two systems may be clearly perceived by considering the exhaust system as having a single outlet, but a multitude of inlets; while the pressure system has numerous outlets, but only one inlet. The purity of the air supply must be controlled at the inlet, and it is practically much easier to supervise one large inlet than a multitude of small ones. Otherwise, the real points of difference in the two systems are unimportant.

Usually the terms **exhaust** and **pressure** are applied only to those systems which are operated by fans or steam blowers, but the same difference in principle exists between those operated by heat or gravity. Thus, the **aspiration** system, which depends upon the draft of a central foul-air chimney, is essentially an exhaust system, because the pressure within the rooms is slightly lower than in the external atmosphere. The ordinary **natural-draft** system, operated by a hot-air furnace or by indirect radiators, is in principle a pressure system, the internal pressure being a little above that of the atmosphere. The difference in either case is the measure of the force of the draft.

THE ASPIRATION SYSTEM.

272. In this system, all of the foul-air flues are brought together and connected into a single large chimney or shaft, so that there is practically only one outlet. There are three methods in vogue of arranging the flues and the movement of the air:

1. To carry a separate flue from each room to the attic, where they converge into a few large ones and finally enter the base of the aspirating shaft. The shaft, in this case, starts from the attic and does not extend down through the lower stories.

2. To carry each foul-air flue horizontally and connect it directly into the aspirating shaft, which in this case must extend through the entire building.

3. To carry the flues downwards into the basement, and connect them to the stack at the lowest practicable level.

In the first and third methods, the number of flues increases with the height of the building, being most numerous in the upper story in the former case, and in the first story in the latter case.

An aspirating chimney which extends to the basement is necessarily much more expensive than one which starts from the attic. The space required for a brick chimney of this kind is considerable, not only on account of the thickness of the walls required in the lower stories, but also because the sectional area necessary to carry the foul air and allow for frictional resistance is so large.

In practice, the velocity of the air will seldom exceed 6 feet per second, and the area of the shaft should be calculated upon that basis. In cases where an exhaust fan or steam jet exhauster can be used, the estimate of velocity may be increased to 8 or possibly 10 feet per second.

273. The principal advantage possessed by the third method over the first is the facility which it affords for using heaters at the base of the stack to aid the draft. A part of the increase in draft pressure gained in that way is spent in overcoming the resistance offered by the foul air while descending the flues to the basement; consequently, the net gain is not very great.

When an aspirating fan or a steam jet exhauster is employed to increase the draft, instead of a heater of some kind, the advantage of cost and convenience is largely in favor of the first or upward method.

274. During the cold season, the difference in temperature between the foul air and the outer atmosphere is usually sufficient to create a satisfactory draft in the aspirating chimney. In addition, the hot gases from the heating apparatus may be turned into the stack to increase the

temperature and aid the draft. But during mild weather, the temperature difference diminishes, and in summer time it dwindles to almost nothing, on some occasions being actually reversed. The chimney thus becomes impotent and inoperative as the weather becomes warmer, and **auxiliary apparatus**, such as steam coils, stoves, grates, and gas burners, located at the base of the stack, must then be employed to aid in maintaining the ventilation.

275. Steam coils, in order to be effective, should be placed crosswise of the foul-air current, and the pipes should be spaced wide apart, so as to impede the current as little as possible. The requisite number can be used by placing them in several tiers; 1¼-inch pipes should be spaced not less than 4 inches apart between centers.

If the coils are located in the stack, they should be placed horizontally, about as shown in Fig. 88, care being taken to insure perfect drainage. It is poor practice to arrange steam coils vertically and around the sides of the stack, because only a small part of the air will come into actual contact with them and be properly heated. The coils should be placed as low down in the stack as practicable, in order to secure the greatest available height for the column of warm air, and every foul-air inlet should enter below, never above them.

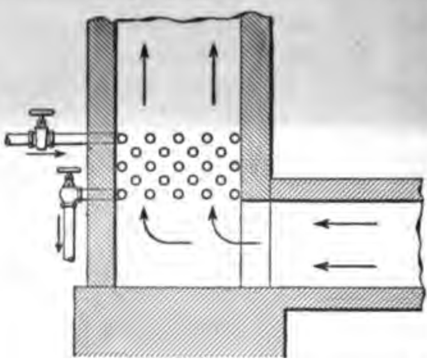


FIG. 88.

THE NATURAL DRAFT SYSTEM.

276. In this system, the air is permitted to circulate without any artificial force. In the better class of dwellings, special flues are provided, by which the foul air may pass out; but in the majority of cases it escapes only through

incidental outlets, such as openings around the window casings, loosely fitting window sashes, cracks in the plastering and walls, through transoms, under doors, etc.

The problem of ventilation by this system is always combined with the question of heating. The air is moved solely by heat, which is usually applied before it enters the room. The quantity of fresh air that may enter the room depends upon its temperature, and upon the rate at which heat is lost by cooling, etc. The main object is usually to maintain a certain temperature in the apartment, the fresh air being regarded principally as a carrier of heat. If the cooling process goes on slowly, the quantity of hot air admitted must be reduced, regardless of the needs of ventilation. Thus, this system operates so as to provide the greatest supply of fresh air in very cold, windy weather, and the least in moderate, still, and humid weather, just the reverse of what should be the case. The natural ventilation system is useful in small buildings only; it is a failure in large or crowded buildings, such as churches, schools, etc.

FORCED BLAST.

277. The use of a fan to create an excess of air pressure, or **plenum,** in the interior of a building makes it practicable to secure perfect ventilation at all times, regardless of wind or weather. The certainty of its operation, and its ability to furnish more air if required, are features of great value.

Another important consideration is that the fan may be located at any point which may be most convenient, either at the bottom of the building, or at the top. It may be placed in another building, even on the opposite side of the street. The system of air supply may be operated from above, in a general downward direction, or in the reverse way, as may be best adapted to the situation.

The heating apparatus employed in conjunction with a fan may be of any variety desired, either steam, hot-water, or hot-air furnace. The use of a forced blast enables the heaters to operate with the maximum degree of efficiency, and to

accomplish the work required with the minimum area of heating surface and of flues.

In selecting centrifugal fans, small wheels and very high speeds should be avoided, because they are very liable to be noisy. Large wheels waste less power, and have the advantage of possessing a large reserve capacity, which may be brought into use at any time by increasing the speed.

The use of belting or friction gears for driving fans should be avoided whenever possible. The engine or motor should, if convenient, be connected directly to the fan shaft.

COMBINED SYSTEMS.

278. It is common practice to use the aspiration and natural draft systems together, and in many cases it would be difficult to fix the line of demarcation between them. One system naturally supplements the other, and the combination is usually an advantageous one.

There are many instances, also, in which the exhaust system is used in combination with a pressure or plenum system, both being operated by fans. Under all ordinary circumstances, this combination is not to be recommended. It does not afford any particular advantage, and there are several substantial objections to it. The cost for flues, fans, power, motors, installation, and attendance is greater than in a simple pressure system of equal aggregate capacity.

The exhaust and pressure fans, in a combined system, handle the same air in succession; consequently, one of them is sufficient to furnish the required volume. In order to do the same work with a single fan, it is necessary only to increase the pressure to the total of that produced by the two. This may be done by increasing the peripheral speed of the fan wheel, either by enlarging the diameter, or increasing the speed of rotation—usually both. The larger single fan will cost much less than the two smaller ones, and will require less care and attention to maintain it in good order.

The single fan will require only about 65 to 75 per cent.

of the power consumed by the other two, the saving being due to the smaller waste by friction. The motor or engine will also cost less than two motors required for the other fans. There is also a considerable advantage in favor of the single fan in the matter of space occupied, and cost of installation.

MIXING VALVES, FLUES, AND DUCTS.

279. Mixing valves are indispensable to the success of any system of ventilation. They form the only practicable method of quickly regulating the temperature, and at the same time securing an unvarying amount of fresh air.

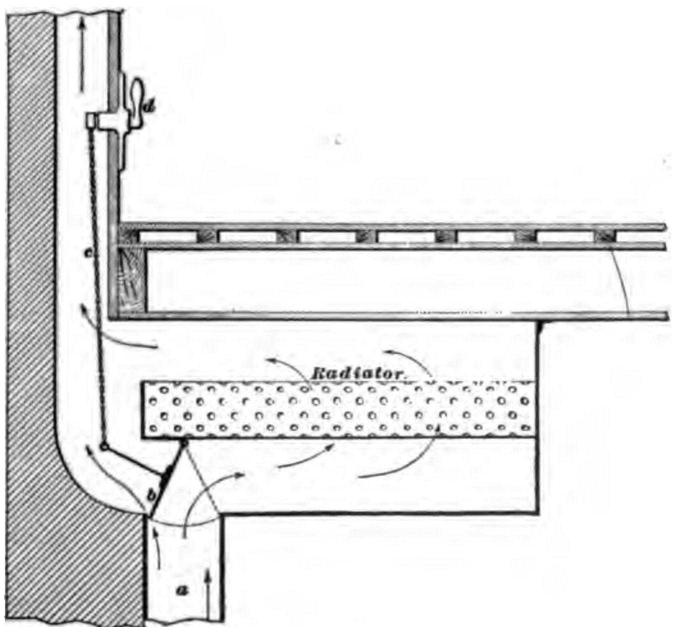


FIG. 80.

The registers which are commonly used for controlling the admission of air to rooms, having louvres or valves that can be opened or closed, are all wrong in principle and should be discarded. Notwithstanding the fact that they are almost

universally used with indirect-heating apparatus of all kinds—steam, hot-water, and hot-air furnaces—yet they are radically defective in the most important particular. They do not permit the heat to be shut off without shutting off the supply of fresh air at the same time.

In large rooms which are supplied with fresh air at several points, it is desirable that each flue should be provided with a separate mixing valve, so that the temperature of the several air-currents may be varied independently when required. Fig. 89 shows an ordinary indirect radiator box, having a cold-air inlet at *a*. A swinging valve *b* is hung near the end of the radiator, in such a manner that it can be made to deflect any proportion of the air-current and compel it to pass over the heating surfaces. The valve is operated by means of a chain *c* and a weighted handle *d*.

The importance of the improvement in ventilation to be made by using these devices is not understood or appreciated, either by the public, who are vitally interested in the matter, or by the architects and others who supply heating apparatus.

280. In designing a system of flues for warming and ventilating purposes, it is necessary to carefully consider not only the proper dimensions, but also the efficiency, durability, convenience, and cost of construction.

The velocity of the air-current in wall flues and in branch conduits should always be made lower than in the main trunk pipes, not only for the purpose of reducing the frictional resistance, but to avoid delivering the air into the rooms at a velocity too great to be easily controlled and diffused, and also to prevent perceptible drafts.

When the air is driven by a fan, the velocity may be 20 feet per second in the main flue, and somewhat less in the large branches, but should not exceed 10 feet per second in the wall flues. With the aspiration system, only half of these velocities can be obtained.

Brick flues should be plastered on the inside in order to present a smooth surface to the air, and especial care should

be taken in this particular when the aspiration or natural draft system is to be employed.

281. Metal flues possess the advantage of being easily made to any reasonable shape, thus permitting round corners and easy curves; a further advantage is that of occupying less space than any other kind. Where they are exposed to moisture, or to the corrosive action of plaster or mortar, their durability may be insured by coating them thoroughly with asphaltum.

In the plenum system of ventilation, arrangements are often made to carry hot and cold air separately in duplicate flues. Usually the flues are made of equal size, but in most cases this is not necessary, because the volume of cold air required for tempering or mitigating the temperature of the hot air-current is usually considerably less than the volume of hot air.

282. Arrangement of Flues.—The general method to be adopted in arranging the main distributing flues (or ducts) and branches in the basement of a building depends upon the system of ventilation to be employed, and upon the arrangement of the heating apparatus—whether concentrated or distributed.

With the plenum system, there are several methods in common use, as follows:

1. The main flue, or duct, is carried along the center line of the building, and lateral branches are extended right and left to the vertical ducts in the side walls. If these are numerous, the aggregate length of the branches is liable to become excessive, causing too much frictional resistance, and entailing unnecessary expense.

2. The main flue is divided into two branches, one of which extends along each side of the building and supplies all the vertical flues on that side. The connections to the wall ducts are then made direct, or nearly so. In many cases this plan is more economical, in the matter of piping, than the previous one.

3. An air chamber is located in the central part of the

basement, and the air is conveyed to the various vertical ducts by means of pipes extending radially from the central chamber to the points desired. This plan is suitable only for small buildings. If the pipes are very long, or are numerous, it is likely to prove an expensive and cumbersome arrangement.

4. The entire basement, or a large part of it, is made air-tight, and is employed as a reservoir for fresh air. This plan is suitable for all classes of buildings where the basement is not required for storage purposes. Where this system is adopted, great care must be taken to make the floor or bottom perfectly water and gas tight, so as to prevent the entrance of moisture or earth gases; all drain and soil pipes must also be rigorously excluded from the rooms used for air storage.

5. A vertical air-shaft, extending from the basement to the top floor, is located in the central part of the building, horizontal branches, more or less subdivided, being taken off at each story. In buildings of three or more stories in height, this plan is usually an advantageous one.

6. The fan delivers the air into a chamber which is divided into two parts, one for hot and the other for cold air. Each wall flue is connected to this chamber by a separate and independent pipe, and each pipe is provided with a mixing valve which delivers air from either the hot or cold chamber, as desired.

283. Improper Outlet for Foul Air.—The practice of using the attic of a building for a foul-air receiver, as frequently done in schoolhouses and similar buildings, is highly objectionable. The usual arrangement is to terminate the foul-air flues at the attic floor and permit them to discharge freely into the space above. Sometimes an aspirating shaft is attached to the roof to aid in discharging the foul air, but usually it finds its way out through slatted windows and similar openings. The wind has comparatively free access to the whole space, and while it blows, an increase of pressure is likely to exist, which is liable to cause a blow-down in the

flues. This trouble could be prevented by connecting each flue to an aspirating shaft. The force of the draft would then be greatly augmented throughout the entire building.

AN UNSANITARY ARRANGEMENT.

284. The problem of disposing of the sewage matter from schoolhouses is sometimes a difficult one, especially where no water supply is available for water closets. A system designed to meet the wants of such cases has been introduced within recent years under the name of the *dry-closet* system. This should not be confounded with the well known *dry-earth* system, which is quite unobjectionable on sanitary grounds.

This dry-closet system is operated by an aspirating chimney, usually the same one which draws the foul air from the schoolrooms. The closet seats are located in the roof of a tunnel leading to the chimney, and each seat is provided with a cover which is intended to be kept closed when not in use. The liquids are sometimes drained off, but the solid matters remain on the floor of the tunnel, and are gradually dried by the current of air which passes over them to the chimney. At the end of the school term, the deposits are saturated with kerosene, and then destroyed by fire.

The foul air from the schoolrooms is drawn directly through the tunnel; consequently, whenever a blow-down occurs, not only will the foul air be driven back into the rooms, but the noxious effluvia of the tunnel will be carried back with it.

As drying and evaporation can take place, in this case, only by absorbing heat from the air-current, it is evident that the temperature of the foul air will be lowered somewhat, and the draft of the chimney will be weakened correspondingly. Sometimes a small grate fire is maintained at the entrance to the tunnel or the base of the chimney, to maintain the draft in mild or warm weather, when the heating apparatus is not in use.

In some cases, a separate chimney is provided for the dry

closet, and the air is taken only from the room containing the apparatus. The result of a blow-down, however, is the same as in the previous case, except that the communication with the interior room is a little less direct.

The seats in these dry closets are always at a higher level than the inlet for air; consequently, the effluvia in the tunnel always tend to flow out into the room whenever a cover is raised. Usually the chimney draft is sufficient to counteract this tendency and prevent any outflow, so long as only one or two covers are opened; but when all the seats are in use at the same time, as often happens, at recess and other occasions, the draft is wholly inadequate. It is then found that while air flows inwards at a few of the seats nearest the chimney, the vile tunnel air flows out unchecked at the others.

285. Another very serious objection to this system is that much of the fecal matter is reduced, by drying, to the condition of dust, and is carried up the chimney. If this matter happens to be infested with the germs of contagious diseases, these also are dried and projected into the atmosphere. In fact, matter is thus carried into the air that ought to go into the earth. All dust eventually descends to the level at which people breathe; thus, the effect of this apparatus is to disseminate filth and disease germs broadcast over the surrounding country. The dry-earth system, in which all fecal matter is mixed with dry absorbent materials, is free from all such objections.

The dry-closet system of heating and ventilating schoolhouses, as it is done today, is a disgrace; it is one of the worst disease breeders that can be devised in schoolhouse construction.

PRACTICAL VENTILATION.

286. The requirements for the successful ventilation of the various classes of buildings which are occupied by human beings are alike in principle in all cases, and have been fully considered in the preceding articles. The

architect should bear in mind that ventilation is a sanitary necessity, and should realize that the physical health of those who occupy the premises depends in a large degree upon the skill and faithfulness with which the work is planned and executed.

Considering the matter from a sanitary standpoint, the problem of ventilating an ordinary dwelling, containing from four to eight rooms, must be regarded as the most important, because the vast majority of our people are housed in that kind of building, and are vitally affected by the conditions prevailing in them.

Schoolhouses come next in importance, being occupied by large numbers of children for from four to six hours per day. Children are much more susceptible than adults to insanitary influences, and must therefore be guarded with the utmost care.

Next in importance are the manufactories, containing large numbers of people engaged in labor for from eight to twelve hours per day. Public buildings, such as theaters, churches, audience rooms, and legislative halls, although they receive the greatest share of public attention, are really of less importance to the sanitarian, because they contain comparatively a smaller portion of the population, and are occupied only for short periods of time.

The chief impediment to good domestic ventilation is the expense of the apparatus. Much of the apparatus now on the market is needlessly complicated and costly, and is encumbered with numerous "attachments" which are more profitable to the vender than the purchaser.

287. It is impracticable to ventilate a dwelling in a proper manner while *direct* heaters of any kind are used for warming it. The heaters, whether stoves or radiators, must be converted into *direct-indirect* or *indirect* apparatus; and the foul air must be vented positively and continuously. The inlets and outlets of each room must be managed so that there will be no considerable difference of temperature in any part of it.

These results can be attained only by employing some system of aspiration, mechanical ventilation being assumed to be impracticable on account of expense. Foul-air ducts of suitable size, and having sufficient height to draw well, must be provided; they are, in fact, indispensable.

These ducts should be brought together and connected into a good chimney. The smoke pipe from the kitchen stove or the heating apparatus should extend up through this chimney such a distance that there will be no chance of having a poor draft for the fire. The pipe inside of the chimney should be made of cast iron, to withstand corrosion, and it should be braced so as to stand in the center of the flue rather than at one side. It is better to make one large flue, with a smoke pipe inside of it, than to build a pair of flues, one for foul air and the other for smoke. In all but the smallest dwellings, two such foul-air chimneys should be provided, one taking the smoke pipe from the kitchen range, and the other from the furnace or boiler. This permits the foul air to be disposed of with a minimum amount of piping.

The doors and windows should be made as nearly *air-tight* as possible, so that cold air cannot enter the building except through the proper channel, that is, through the heating apparatus.

288. One of the chief difficulties to be found in securing a proper distribution of warm air in the several stories of a dwelling is the draft that always exists to a greater or less extent on the stairway. An upward current of considerable force prevails here at all times while the heating apparatus is in use, and if there is any mode of escape for air at the top, this draft will be so strong as to interfere with the proper suction of the foul-air flues. While this trouble may be avoided by enclosing the stairs and placing doors at the foot or head, this remedy is usually so objected to that it may be dismissed as impracticable.

If the hall is located in the middle of the building, so that it is warm on both sides, the stairway draft may be utilized

to operate the ventilating system. The foul air may then be drawn out from each room into the hall through the space under the doors, these spaces being made of proper size to serve as foul-air exits.

At the top of the stairway the air should be discharged through an aspirating shaft, and not through a skylight or ventilator. If the skylight is used for this purpose, a current of cold air is likely to enter at one part of the opening, while warm air flows out of the remainder; thus, the cold air will pass down the stairs, making very unpleasant drafts.

When the hall is employed in this manner, all the larger rooms, especially those on the first floor, should be provided with additional foul-air outlets. An open fireplace serves excellently for this purpose, provided the opening into the chimney is not too large or too far above the floor. A fireplace, as explained on another page, is a poor contrivance for heating purposes, but it can be made a useful assistant to ventilation.

289. In **dining rooms** and **parlors**, where gas burners or oil lamps are used for illumination, it is a good plan to enclose the lights in glass, and provide them with a special draft tube connected to the foul-air flue. This arrangement not only disposes of the products of combustion, but it will, if properly constructed, add considerably to the brilliancy of the light. It also furnishes a local vent which serves admirably to clear the room of the fumes of cigars, etc.

290. A common method of ventilating **sleeping rooms** is to provide two openings into the hallway, the door being raised an inch or more above the floor, and the transom being opened above it. This device, however, is inoperative, because there is no force tending to drive the air either way through these openings. If any fresh air reaches the occupant of such a room, it will be by leakage through or around the window. If the window is open, and the weather is quiet, the air from the hall is likely to pass through the room and escape at the window, thus making the chamber a passageway for vitiated air.

291. The **bathroom** should be thoroughly ventilated and warmed. As usually constructed, in the smaller class of dwellings, the bathroom is but little larger than a closet; and when a warm bath is taken, the air is quickly vitiated, to a serious degree, by the combined effects of moisture, heat, gas burners, and respiration. Where no positive ventilation is provided, this bad air, in conjunction with a warm bath, is very exhausting. The practice of ventilating a kitchen into a bathroom is entirely wrong, and should not be allowed.

292. The **water closet** should be provided with a special ventilating flue, or *local vent*, and care should be taken to insure a draft in it that will never be reversed. This pipe should take air from under the seat, and should, if practicable, be run alongside of the kitchen chimney, and up to the top of the building, independently of all other pipes, and should also be provided with a gas burner or other artificial heat to secure a positive draft when the chimney is cold. Outlet registers in water-closet apartments should be set close to the water-closet seat.

293. All **clothes closets** should be ventilated, especially those which receive undergarments or soiled clothing. The openings from these closets should be protected with fine screens to keep out moth millers, etc.

294. The **kitchen** and **laundry** should be ventilated independently of the other parts of the house, and if there is any door opening directly from them into the hall or stairways, it should be made practically air-tight, otherwise the odors of cooking, etc. will pervade the halls and upper rooms.

295. The ventilation of the **cellar** is a matter of great importance to the health of the family, yet in the majority of dwellings no provision is made for it, and it is not even supposed to be necessary.

The necessary ventilation can be secured by running a flue from the *highest* point in the cellar, usually the top of

the stairway, up to the roof, placing it in some interior wall where it will be reasonably warm. The proper size for this flue depends upon the character of the cellar—whether wet or dry—and the nature and quantity of materials stored in it. Ventilation is needed most when the place is both warm and moist, because fermentation then proceeds with the greatest freedom, and molds and fungi flourish vigorously. It is not advisable to merely make an opening into one of the chimneys for ventilating purposes, because it will probably spoil the draft of the stove or heating apparatus connected to it.

The presence of a furnace or boiler in a cellar helps to ventilate it, by passing a considerable quantity of air through the fire and up the chimney. The quantity thus removed, however, is quite insufficient unless the cellar be small, very clean, and unusually dry.

296. The **first floor** in a dwelling should be made gas-tight, in order to prevent the cellar air from passing through and mingling with the air in the living rooms. This is best done by laying the floor in two thicknesses, with a thick layer of tarred paper between them. Ordinary building paper is quite inferior to the tarred material for this purpose. This floor should extend to the outer walls of the building and be made air-tight around the edges, so that no air can possibly pass up from the cellar into the spaces between the studding or furring strips.

In the cheaper class of frame dwellings, it is a common practice to leave these spaces open, so that they form flues, up which the cellar air passes to the attic without restriction. The ventilation thus afforded, although quite unintentional, has probably saved the inmates of such dwellings, in a multitude of cases, from the sickening effects of bad cellars that otherwise would have been deadly. The existence of these flues or passages is highly objectionable on another account, namely, that they permit heat to escape through the walls with undue rapidity. All circulation of air within them should be prevented, either by putting in tight horizontal

partitions at short intervals, or, better still, by filling the spaces with mineral wool or other non-conducting materials. Brick and mortar are not desirable for this purpose, because they absorb a great deal of moisture, and tend to rot the woodwork.

297. Fireplaces.—The open fireplace is an exceedingly inefficient form of heating apparatus. It passes so much air up the chimney that the heat radiated from the fire is quite insufficient to warm the fresh air rushing into the room to take its place, to a sufficient degree to be comfortable. It is impracticable to warm rooms satisfactorily by means of the open fireplace, if the external temperature is much below 32°.

When the thermometer falls to 10° or lower, it appears as if the room becomes colder the more the fire is made up, until it seems as though the inmates would eventually be frozen. In some cases, fireplaces are constructed so as to warm the fresh air before entering the room, by passing it through a heating flue; but all such arrangements are faulty in principle, and are unable to remedy the trouble to such an extent as to be of any value. The fresh air is delivered so near to the fireplace that it passes almost immediately into the fire, and thus leaves the remoter parts of the room to freeze as before.

The ordinary fireplace wastes 90 per cent. or more, and even the most improved varieties are believed to waste not less than 80 per cent. of the heat given out by the fuel. It is obvious, therefore, that their use is restricted to places where expense is not objected to, and to localities where the temperature does not descend below the freezing point.

They may be employed to good advantage, however, in colder climates, by using them as auxiliaries to the principal heating apparatus, putting fires in them only when the weather is extremely cold.

298. Summer Ventilation.—During warm weather, when the heating apparatus is not required, a building can

be abundantly flushed with air by opening the doors and windows. But it is necessary, nevertheless, to make provision for proper ventilation during stormy weather, when all outer doors and windows must be closed.

To accomplish this, a register should be provided near the ceiling of each room to provide for the escape of foul air, in addition to that near the floor, because the latter is practically inoperative at this season. These top or ceiling registers are suitable only for summer use, and should be tightly closed at the end of the season when the heating apparatus is started up.

EXAMPLES OF VENTILATION AND HEATING.

299. Fig. 90 shows a good arrangement of heating and ventilating apparatus in a small frame dwelling. This house represents a class which is very numerous in the country and suburban districts. It is two stories high, except the part containing the pantry, which is a one-story addition.

The heating is performed by a hot-air furnace *d*, and the ventilation is secured by an aspirating chimney *f*. The draft in this chimney is aided by the heat emitted from the furnace smoke pipe *e*, which passes up through the center of it. In order to be durable, this pipe must be made of cast iron; common wrought-iron or galvanized pipe is worthless, being quickly destroyed by corrosion. The smoke pipe from the kitchen range should be connected into this pipe, so as to aid ventilation when the furnace is not in use.

The hot-air registers are located near the ceiling and in the extreme outer corners of the rooms; the foul-air outlets into the chimney are made near the floor. A second set of outlets near the ceiling are provided for use in summer time. It will be noted that the vertical hot-air ducts are carried up inside the room, instead of between the studding in the interior of the walls. The reason for this is that the walls are usually too thin to permit the use of a proper-sized flue, or to permit it to be properly protected against loss of heat. In the arrangement shown, a layer of good non-conducting

material 1 inch thick is interposed between the wall and the ducts, as shown at *a*, *b*, and *c*. The other surfaces of the ducts are merely painted, or papered, or encased with thin wood, so as to present a satisfactory appearance, and also protect them from injury.

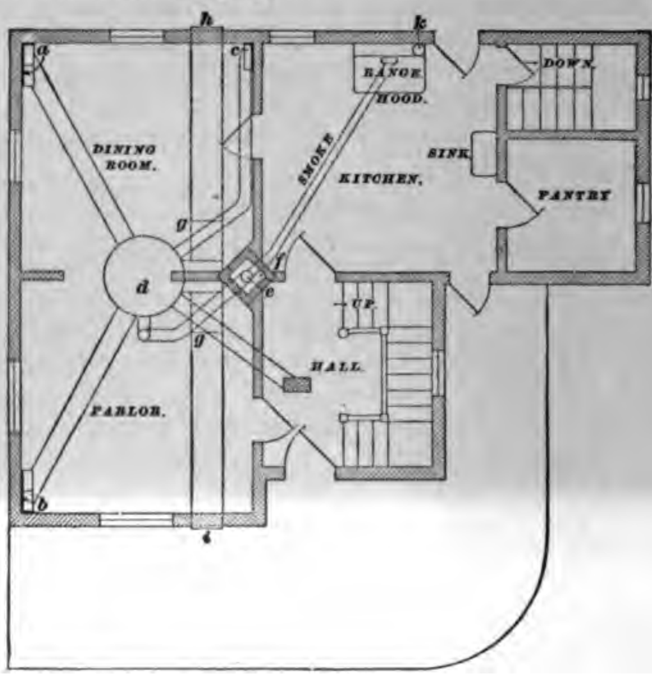


FIG. 90.

The best non-conductors for this purpose are either coarse wool or hair felt, or thin slabs of magnesia, sometimes called "mackite." If these are too expensive, a good sound pine board, free from knots or resinous spots, may be used instead. Paper will not afford sufficient resistance to the escape of heat, unless it be applied in many thicknesses, forming a layer at least half an inch thick. Common mortar or plaster is of very little use for this purpose.

300. Instead of connecting each vertical duct to the furnace by a separate pipe, as furnacemen usually insist upon

doing, only one leader is used to supply each group; this should be covered with non-conducting material. The second-story flues are throttled at the bottom where they join the leader, so that they will not take an undue share of the hot air.

The hot-air register in the hall is placed in the floor, instead of in the wall, so that it may serve conveniently as a foot warmer, etc. The draft at this register is likely to be good, unless there is a considerable infiltration of cold air through the walls and around the outer door and windows.

The kitchen range is provided with a hood and a ventilating pipe *k*, which extends upwards to a point above the main roof and is provided with a proper cowl. This pipe should be provided with a damper, to prevent a back draft of cold air during the night time, when the fire is low, and to prevent loss of heat during cold weather. This arrangement adds greatly to the comfort of the kitchen, and more than repays for the extra outlay incurred.

301. The cold-air flue extends from the front to the rear of the house, and is provided with a tight shutter or slide at both ends, *h* and *i*. It is carried along overhead under the floorbeams, and is connected to the base of the furnace by inclined pipes *g*, which dodge the hot-air pipes and the smoke pipe.

In order to make a success of this system of ventilating and heating, the building must be made as nearly air-tight as possible. The walls must be made impervious at all points, and the circulation of the air between the joists and floors must be stopped. The windows and outer doors should be made wind-tight by means of packing or weather strips. It is essential, also, that the aspirating chimney *f* should be extended well above the main roof, and the top should be provided with a cowl, or so constructed that the wind will aid rather than impede the draft. The success of the whole system depends upon having a good draft in this chimney.

302. Hot-air furnaces are always objectionable, because they vitiate the air with gas to a greater or less extent; a much better quality of air can be secured by using a hot-water heater instead. The radiating coils may all be concentrated in one box, which is located in the same place as the furnace, and the warm air may be distributed by the

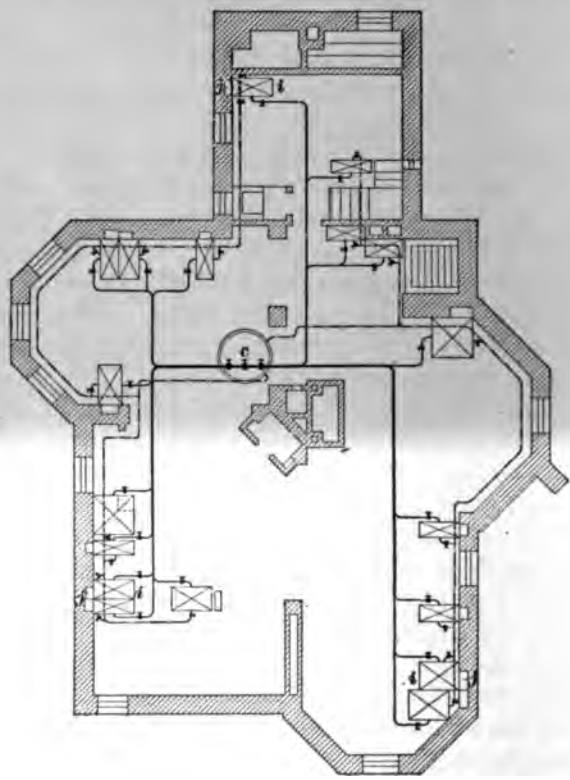


FIG. 91.

pipes shown. Fairly good results may be achieved by using radiators in each room, but in this case each radiator should have an independent supply of fresh air, and should be encased so as to deliver the warm air at the top of the room, as described in a previous article.

303. Figs. 91 to 95 show the arrangement of flues and apparatus for ventilating and heating a suburban residence of moderate size. The ventilation is effected by an aspirating chimney, and the heating is performed by indirect hot-water apparatus.

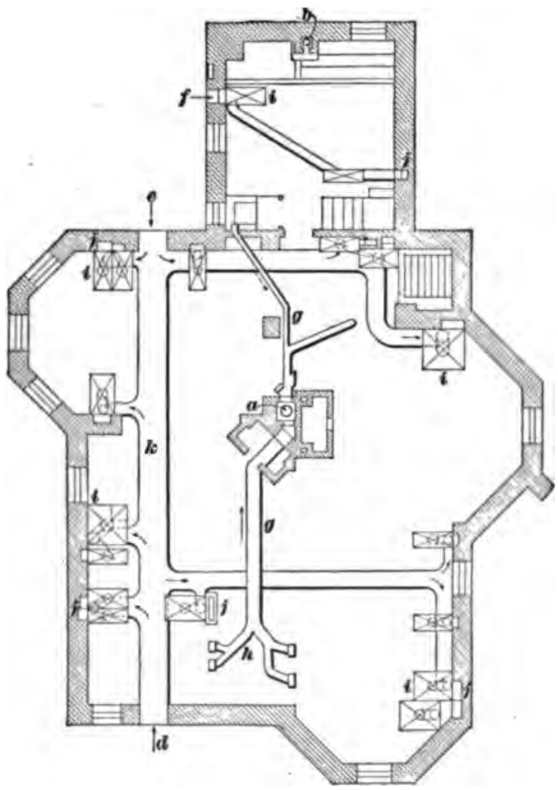


FIG. 92.

The aspirating chimney a is 25 inches square inside, and the draft is aided by a 10-inch smoke pipe from the boiler, which passes up through it. Another aspirating chimney b is provided in the kitchen for the use of the rear part of the house. This latter chimney is made 18 inches square, and the smoke pipe within it is 8 inches in diameter. The

water closets are vented locally by this chimney instead of the other, so that effective ventilation may be had at all seasons of the year. Figs. 91 and 92 are both basement

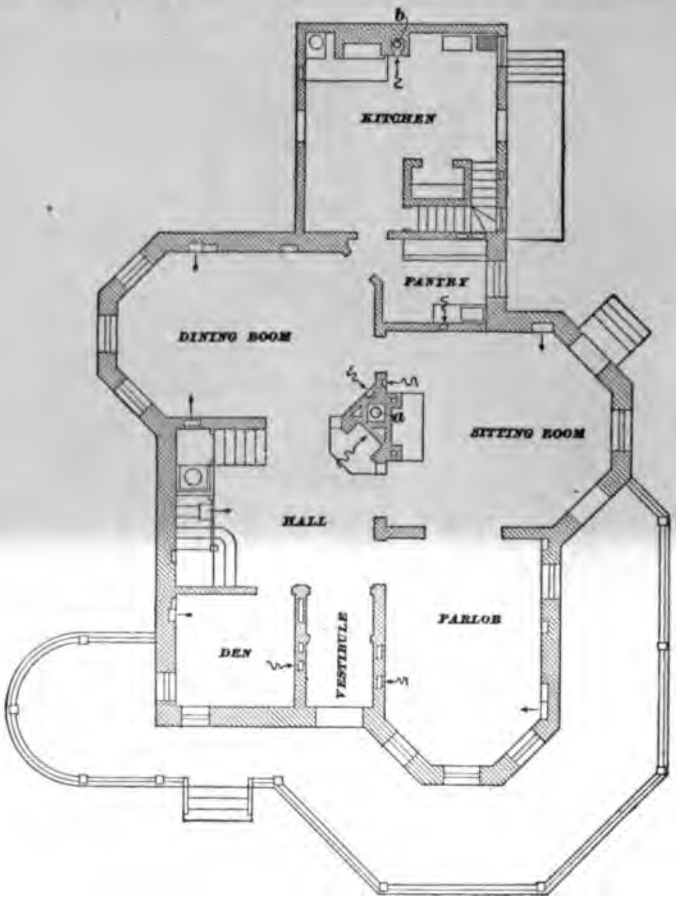


FIG. 93.

plans, one showing the radiator stacks *i* and hot-water piping, and the other showing the cold-air ducts *k* and the main foul-air flues which discharge into the central chimney. The flow pipes are shown in solid lines, while the returns are indicated by dotted lines. The boiler is shown at *c*.

The cold air enters through windows at *d*, *e*, and *f*, the last named being for the radiators in the rear. It then enters the casings of the indirect stacks on their under side, passes

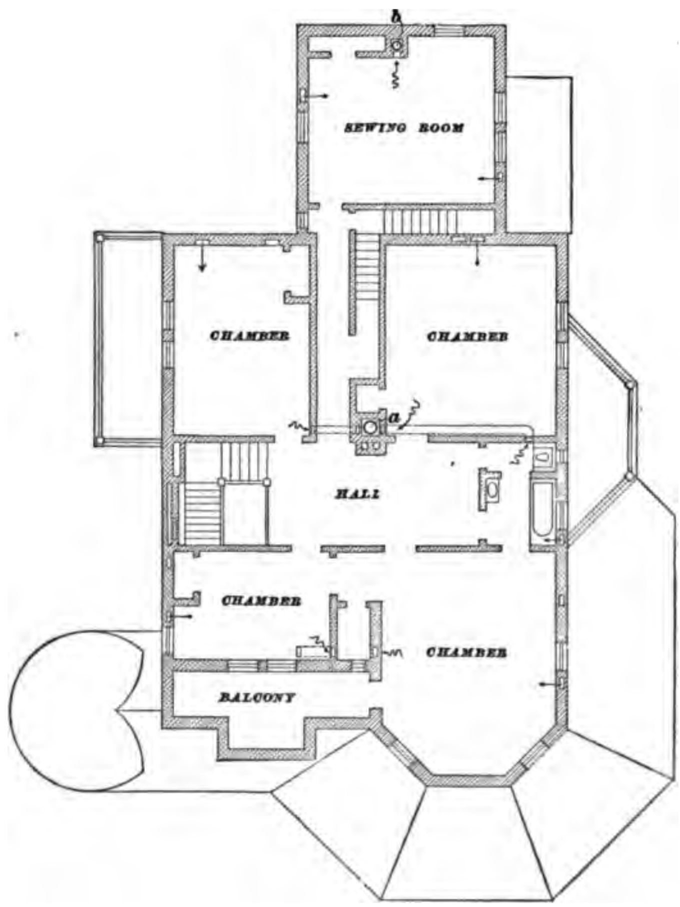


FIG. 94.

up between the radiator surfaces, and flows into the several rooms through the hot-air flues *j*, which are built in the walls. All the foul-air ducts from the rooms on the first and second floor are led downwards to the basement, where

they connect with the main flues *g* and *h*. On the third floor, however, they discharge directly into the chimney, as shown in Fig. 95. All the hot-air inlets are located about 6 inches below the ceiling, and the foul-air outlets are placed on the opposite side of the room, just above the baseboard. It will be noted that the warm-air registers are located in cold outer walls, while the foul-air ducts are run only in warm interior walls.

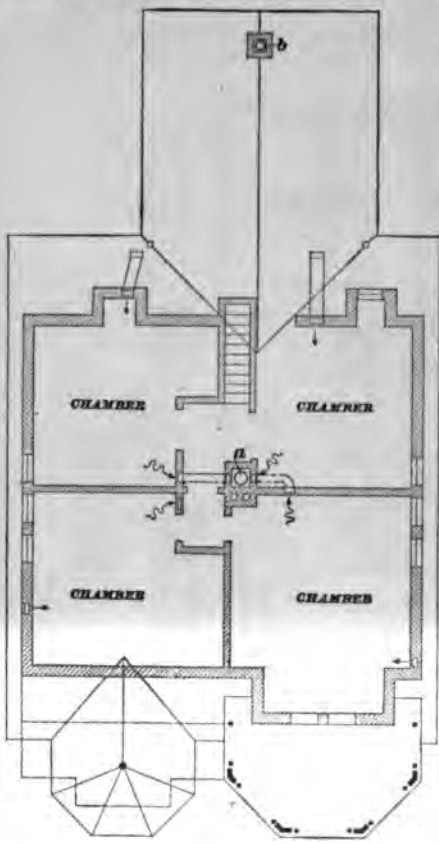


Fig. 95.

304. Figs. 96 and 97 show an ordinary two-story schoolhouse, of eight rooms, ventilated and heated by modern methods. The fresh cold air is taken down through a shaft *a*, which extends sufficiently far above the roof to insure its not being seriously interfered with by the wind. It is then driven by a centrifugal fan *b*, through a heater *d*, and is delivered to the vertical ducts *h*, by the pipe *e*; the foul-air vent is shown at *v*. A part of the air passes around the heater and is delivered cold to the wall ducts by the pipes *c*. The hot-air flues for the various rooms are made separate, and each one is provided at its foot with a mixing valve, so that the temperature of the air supplied to any room may be quickly changed without affecting any of the

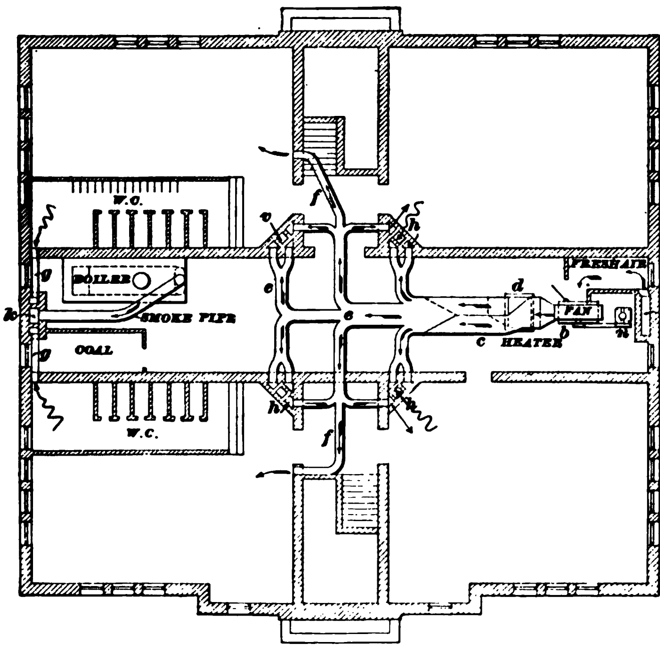

W.C.
BOILER
SMOKE PIPE
COAL
W.C.
FRESH AIR
FAN
HEATER

FIG. 96.

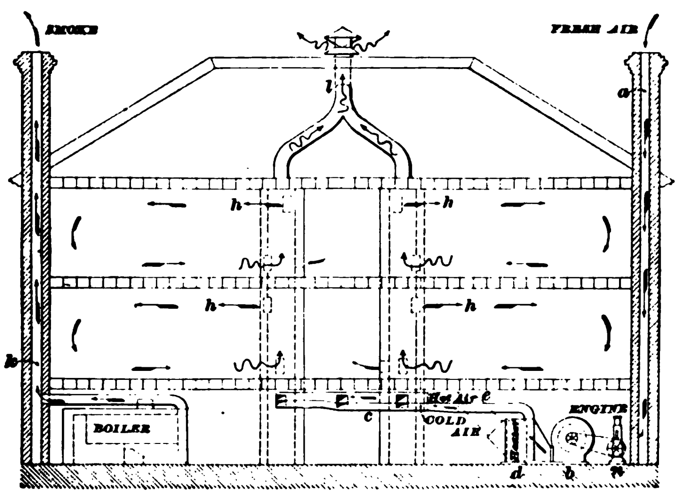

SMOKE
FRESH AIR
BOILER
Hot Air
COLD AIR
ENGINE

FIG. 97.

others, and without diminishing the volume of the air supply. Both the heating and ventilating flues are located in the inner corners of the rooms, the hot-air register being near the ceiling, and the foul-air outlet near the floor.

The basement rooms containing the water closets are supplied with air by means of the pipes *f*, the foul air being taken out by the flues *g* which run up alongside the smoke stack *k*.

All the other vent flues are run to the attic separately, and are there united into a single stack *l*. No cowl or other protection is needed over the top of this outlet, if provision is made at its base to drain off any rain that may fall into it.

No radiators are used at any point, except in the main corridor on the first floor, and two of these are arranged just below the level of the floor, to serve as foot warmers. All the other heating surface is concentrated in the heater, where it can operate with the greatest efficiency. The engine *n* is shown attached directly to the fan.

The attic floor is lined with thick paper and carefully made air-tight, both to prevent any waste of air, and also particularly to guard against the loss of heat from the rooms below.

305. The arrangement of hot-air registers here shown is suitable only for rooms of moderate size. In large rooms, the cooling effect of the outer walls is likely to be so great as to produce a considerable drop in the temperature, making the remoter parts of the room quite uncomfortable. In such cases, the registers must be increased in number, and the warm air must be delivered more directly to the cold part of the room.

Where this cannot be conveniently done, the deficiency in heat may be made up by running pipe coils along the outer walls, especially under the windows. Coils are better for this purpose than radiators, because the heating surface is distributed over a greater space. Each line of pipe should be provided with valves at both ends, so that any number

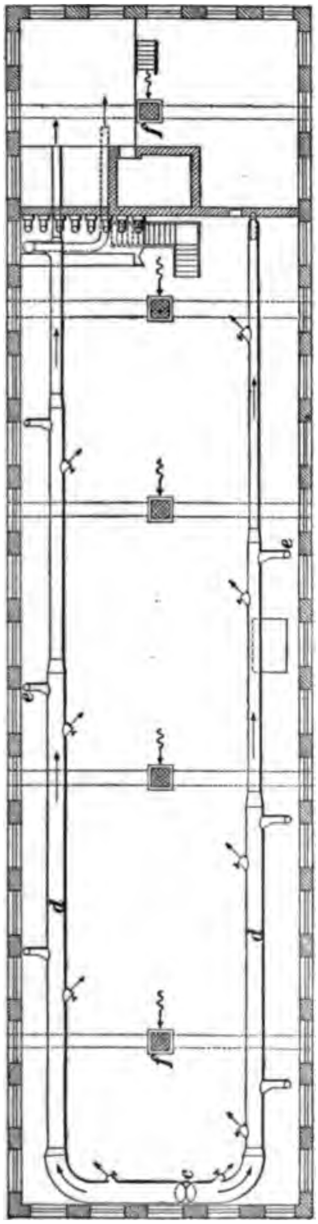


FIG. 28.

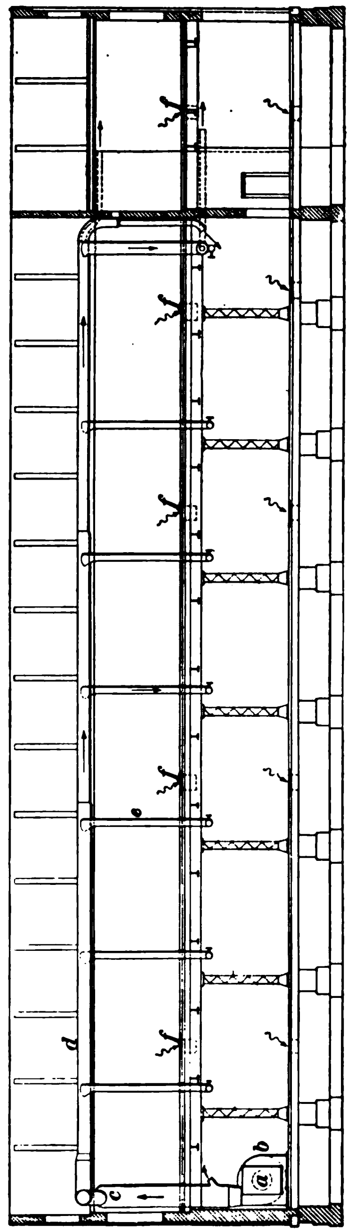


FIG. 29.

of them may be shut off if desired; otherwise, they are liable at times to give off too much heat, and become a source of great discomfort to the students sitting near them.

The **clothes closets** or "cloak rooms" should be separated from the class rooms, and should be thoroughly ventilated, independently of all other rooms. They should also be so arranged that they may at times be tightly closed for purposes of disinfection.

306. Figs. 98, 99, and 100 show a manufacturing establishment, two stories high, 50 feet wide, by 200 feet in length. The fresh-air supply is driven through a steam heater *a*, having 4,000 square feet of tube surface, by a fan *b*, which has a wheel 72 inches in diameter and 33 inches wide. The hot-air mains are carried up to the roof and are run along horizontally just above the tie-beams of the trusses. Vertical branches are carried downwards to the first and second stories at moderate intervals, and are provided with gates at their outlets.

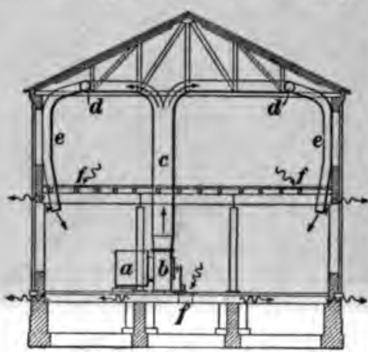


FIG. 100.

This arrangement of piping prevents any interference with shafting and machinery, and the air being delivered at the top of the room, all stagnation or accumulation of foul air is prevented. The foul air is vented through ducts under the floor, which discharge through openings in the outer walls.

The fan takes air from the outside of the building during working hours, and from the inside at other times, when there are but few people in the building. The heating is done principally by the exhaust steam coming from the shop engines, live steam being used only during the night.

PAINTING AND DECORATING.

INTRODUCTION.

1. The painter desirous of obtaining a correct knowledge of his trade should first acquaint himself with the nature and properties of the materials calling for his constant use, and the architect superintending the work of the painter should possess sufficient knowledge of the trade to intelligently criticize the character of the workmanship and materials.

Paint being a protective and preservative of both the structural and finishing materials of a building, edifices should be painted or varnished, according to the character of the material employed in construction, and the composition of the paint or varnish varied to suit the conditions of each case.

The utilitarian phase of painting becomes an element of architectural value, only when considered in conjunction with its decorative effect, wherein it combines the useful with the beautiful, making each administer to, and enhance the value of, the other.

The theory and practice of the painter's art may, therefore, be considered in regard to both plain surface painting and to decorating; the former dealing with pigments—their processes of manufacture, methods of application, and combination of colors, as well as the material best suited for each particular class or part of the work, regard being had to durability and utility; while the latter discusses the character of the material painted, the combinations of colors applied, and treatment of surfaces which are to receive the color, exclusively in consideration of the decorative effect.

CLASSIFICATION OF PAINTS.

COMPOSITION OF PAINTS.

2. All paint is composed of two general ingredients, namely, the pigment and the fluid medium. The former usually consists of a mineral oxide or precipitated vegetable dye, which very largely forms the body of the paint, and determines its color, while the latter consists of the oil, varnish, or water in which the pigment is dissolved or suspended, according to the character of which, the paint is termed **oil color** or **water color.**

Oil colors are used in all places where the purpose of the paint is to protect as well as to decorate the surface to which it is applied, or where the painted decorations are likely to be exposed to the elements. Water colors are used in house painting exclusively for decorative effects, and then only in places where they will not be subjected to dampness or strong sunlight.

3. Pigments are, according to the base from which they are derived, divided into several classes. The metallic oxides give us pigments of various colors, some of which are of great importance to the painter, while others, owing to their chemical influence on other pigments, cannot be mixed to form compound colors.

Various salts of lead produce white, red, and yellow pigments, the most important of which are the whites, as hereafter described. Iron and mercury produce red pigments. The oxides of cobalt give us a valuable shade of blue, and copper forms the base of a number of the most important greens.

The **ochers, umbers, siennas,** etc. are all forms of earth, found in their natural state, already mixed with certain mineral oxides, which impart to them the colors by which they are known.

4. Lakes.—This is the general term given to those pigments, derived from animal, vegetable, or coal-tar coloring

matter. They are usually, according to their particular composition, prefixed by another name to more clearly define them, such as crimson lake, madder lake, etc., madder being the name of that group of pigments made from the coloring matter of the madder root.

5. Carmines.—These pigments are the coloring matter which is derived from cochineal, and they form several combinations with madders and lakes, which will be hereafter discussed.

A knowledge of the metallic bases of the various pigments is, then, most important, as upon their intelligent use and admixture depend the permanence and brilliancy of the resulting colors.

PIGMENTS.

WHITE PIGMENTS.

6. White lead is a carbonate of lead produced by several methods, the best being obtained by the Dutch process, which consists in the taking of gratings of pure lead and exposing them to the fumes of acetic acid. The gratings are, by this treatment, corroded and covered with a crust of carbonate, which is removed and ground to a fine powder.

7. Precipitated white lead is made by suspending rolls of thin sheet lead, or small bars, over malt vinegar or pyroligneous acid in closed vessels, the evaporation of the acid being kept up by heat applied to the vessels, while immersed in a steam bath. The white lead, produced by precipitation, is generally considered inferior to that prepared by corrosion, wanting, as it is, in density or body, and, when mixed with its vehicle, absorbing too much oil. It has, however, one advantage; it requires no grinding to prepare it for use.

8. The following is a simple method by which pure white lead may be prepared when not otherwise obtainable: Procure an earthen vessel, with a cover something like a

colander, but having bars across instead of being perforated. This cover is made of strips of clay well burned. For temporary purposes, however, bars of wood will suffice. Vinegar is poured into the vessel, filling it almost to the bars, on which have been placed narrow strips of common lead rolled into scrolls. These, to remove any accumulated oxide or foreign matter, should be carefully scraped before use, and then so placed over the bars that they do not touch each other. The pot is gently heated, and the fumes of the vinegar corroding the lead reduce it to a white powder ready for mixture with oil.

9. The white lead, used in oil painting, is sold already ground in oil—reduced to a thick paste, much too thick for use, and requiring dilution to bring it to a proper consistency. This is done by placing some of it in a pot, pouring on it a small quantity of oil and turpentine, then stirring the compound thus obtained with a stiff palette knife or flat stick until the particles of the pigment are all separated and a perfectly smooth mixture obtained. Should this, however, still prove of too pronounced a consistency for use, it should be passed through a tin strainer or a piece of canvas, after which driers are to be added, and the paint reduced to the proper consistency for work.

10. There are other white oxides of lead, the heaviest and whitest of which are the best, being, in point of *color* and *body*, superior to all other whites. When pure and properly applied in oil and varnishes, they are safe and durable, and dry well; but excess of oil discolors them, while in water painting they are very changeable, sometimes becoming almost black. They have, besides, a destructive effect on all vegetable lakes, except the madder carmines, and are also injurious to minium, the red and orange oxide of lead; to orpiment, or king's yellow, which is a trisulphide of arsenic; to massicot, the yellow oxide of lead; to patent yellow, a chloride of lead; and to gamboge, a pigment derived from a powdered yellow gum; but with ultramarine blue, vermilion, yellow, and orange chrome, all hereafter

described, and with the lakes, ochers, and siennas, these whites compound with little or no injury.

11. In oil painting, white lead is essential in the ground for dead coloring, or the formation of tints of any color, as it is also in **scumbling,** either alone or mixed with other pigments. (Scumbling is the softening or blending of two or more adjacent colors, by rubbing them over with a brush, or the finger, either dry or charged with additional color.) White lead is, moreover, when neutralized with black, the best local white.

Lead pigments should not, however, be employed in water colors, distemper, crayon, or fresco painting; for, with all such, they occasion change of color, either by becoming dark themselves, or by causing the colors with which they might be mixed, to fade. Cleanliness in using these colors is to be specially enjoined; for, although not virulently poisonous, they are, when taken into or imbibed by the pores or otherwise, pernicious, as, indeed, are all pigments of which lead is the basis.

White lead improves with age. It should not be exposed to the air, or it will turn gray. Old white lead of good quality goes further and lasts longer than if used when fresh. Paint made with fresh lead has, moreover, a tendency to become yellow. Fresh white lead has often a yellowish tinge, caused by the presence of iron.

12. Adulteration.—White lead may be obtained either pure, or mixed with various substances, such as sulphate of baryta, sulphate of lead, sulphate of lime, whiting, chalk, zinc white, etc. These substances do not combine so well with oil as does white lead, nor do they so well protect the surfaces to which they are applied.

Sulphate of baryta, the most common adulterant, is a dense, heavy, white substance, very much like white lead in appearance. Absorbing very little oil, it may be easily detected by the gritty feeling it produces, when the paint is rubbed between the finger and thumb.

OTHER WHITE PIGMENTS.

13. The principal varieties and sources of other white pigments are the following:

Antimony white, from antimonious oxide.

Body white, from levigated flake white.

Cadmium white, from cadmium carbonate or hydrated oxide.

Chinese white, from a zinc oxide.

Constant white, from barium sulphate.

Derbyshire white, from ground baryta or heavy spar.

Dutch white, from barium sulphate $\frac{3}{4}$, white lead $\frac{1}{4}$.

Flake white, an English white lead, in the form of flakes or scales, from which it derives its name, is oxidized carbonate of lead, not essentially differing from the last mentioned. Other white leads seldom equal it in body; when levigated, or ground smooth, it is called "body white." Flake white ranks next in body or density to white lead, and is employed in the better class of work, where great purity of tone is required.

Flemish white is an artificial lead sulphate.

Hamburg white, composed of $\frac{2}{3}$ of barium sulphate and $\frac{1}{3}$ of white lead.

Kremnitz white, from lead carbonate and hydrated oxide.

Kremser white is a pure white lead.

Newcastle white is a white lead made with molasses vinegar.

Pattison's white, a mixture of lead chloride and oxide.

Pearl white, bismuthous oxychloride.

Satin white, aluminum and calcium sulphate.

Tin white, hydrated tin oxide.

Tungsten white, barium tungstate.

Venice white is a mixture composed of barium sulphate and white lead in equal parts.

Zinc white is hydrated zinc carbonate or oxide. It is perfectly durable in oil and water, but unfortunately wanting in body, which renders it less useful to the house painter,

who is more restricted as to the thickness and number of coats he applies, than is the artist, who, in this respect, enjoys greater latitude. In house painting the use of zinc white is, therefore, resorted to only where extreme delicacy of treatment is demanded.

BLACK PIGMENTS.

14. Black, the opposite extreme of white, is the last and lowest in the scale of colors. To be perfect, it must be neutral with respect to individual colors and absolutely transparent—that is, it must have the quality of absorbing all the rays of light that fall upon it, and reflect none. Its use in painting is to represent *shade* or depth, of which it is the governing element in colors, as white is to *light*.

There is, properly speaking, no perfectly black pigment. Black deteriorates all colors, more or less, with which it is mixed, by neutralizing them and rendering their color valueless. Black is what is known as a *cold* color, that is, devoid of the brilliancy of such colors as red, yellow, orange, etc., which are called *warm* colors.

Black, therefore, imparts coldness to all colors with which it is mixed—it gives, for instance, to red a purplish tinge; it turns yellow into green; and gradually neutralizes white to a bluish gray. It is the most retiring of all colors and communicates this property to other colors in mixture, but when placed alongside of other colors, heightens their effect by contrast, and, in like manner, subdues the cold colors by rendering them less conspicuous. Invested with the double office of color and shade, black is, both as regards use and avoidance, one of the most important colors to the painter.

15. Lampblack is simply the soot obtained by burning resinous woods, tallow, coal tar, etc. It is a purely carbonaceous substance of fine texture and very durable. It may be experimentally prepared by holding a plate over the flame of a candle and collecting the sooty deposit thus obtained. On a larger scale, it may be obtained by suspending a conical metal funnel over a lamp flame, fed with

oil, tallow, coal tar, or crude naphtha, through a large bushy wick arranged to generate as much smoke as possible. Large, spongy, mushroom-like accumulations of an exceedingly fine and very black carbonaceous matter gradually form at the apex of the cone, and may be, from time to time, collected until a sufficient quantity is obtained. It is in this state very oily, and can be used only as an oil pigment, but if slowly calcined in closed vessels, it is rendered drier and less oily, becoming what is known as **burnt lampblack,** which may be used as a pigment for both oil and water colors.

16. **Ivory black** and **bone black,** though prepared by the same process, are pigments that differ materially in their intrinsic qualities. Each is prepared by charring to blackness, in a closed vessel, the material which forms its base, but though both are perfectly neutral and durable blacks, mixing well with oil, the former is superior in quality and may be mixed with certain proportions of white lead, to form a beautiful pearl gray.

Black, furnished from calcined bones, however, has a peculiar reddish tint that mars it for some purposes. It tends, unless well burnt, towards a brown color, drying slowly and unevenly. Bone black is cheaper than ivory black, and is, therefore, frequently used where the latter would be more suitable and yield better results.

17. **Frankfort black** is the name of a pigment prepared from the lees, or sediment of wine, vine twigs, and tendrils—from which the tartar has been washed—by burning in the same manner as ivory black. Similar blacks are also prepared from peach stones, etc., though these are usually distinguished under the names of almond black, peach black, etc., and, in India, the shell of the cocoanut is employed for the same purpose.

Fine Frankfort black, used very largely by copperplate printers, is one of the most valuable black pigments obtainable; being of a fine neutral color, next in intensity to lampblack, and is even stronger in effect than ivory black. Strong

light has the effect of deepening its color, and it is probable that the grays so admired in the works of the Flemish painters, owe their pureness to the use of this pigment in the mixture of their colors.

An inferior quality of Frankfort black is made from the levigated charcoal of woods, of which the hardest, such as box and ebony, afford the best material. This quality is very largely used as the pigment for printer's ink, but is, also, occasionally used as a paint.

18. Blue black is a well burned and levigated charcoal of a cool neutral color, not differing in other respects from the common Frankfort black. Blue black was formerly much employed in painting, and, in common with all carbonaceous blacks, has, when duly mixed with white, a preserving influence upon that color. This influence is obtained from two causes, first, chemically through the bleaching power of carbon, and the other, chromatically through the neutralizing and contrasting power of black with white. A superior blue black may be made by calcining Prussian blue in a closed crucible, in the manner of ivory black, and it has the important property of drying well in oil. Innumerable black pigments may, in this way, be made by charring.

PRIMARY COLORS.

BLUE PIGMENTS.

19. Of the three primary or fundamental colors—red, yellow, and blue, from combinations of which all other colors can be made—blue alone possesses in its entirety that quality technically known as coldness in coloring, and is therefore nearest in the chromatic scale to black. It bears the same relation to shade that yellow does to light, gradually deepening as it does, through various shades of darker hue, until it merges itself into a blue black—its extreme limit.

20. Prussian blue is made by mixing the yellow prussiate of potash with some salt of iron. The prussiate of potash is obtained by calcining and digesting old leather, blood, hoofs, and other animal matter, with carbonate of potash and iron filings. This pigment dries well with oil and is much used for mixing dark blues, for making purples, and for intensifying blacks. Slight differences in the manufacture give considerable variation in tint and color, which causes the material to be known under various names, such as Antwerp blue, Berlin blue, Chinese blue, etc.

21. Indigo blue is a pigment manufactured in the East and West Indies from several plants, but principally from the anil, or indigofera. It is of various qualities, and has been known as well as used, for many centuries, in dyeing processes. In painting it is not as bright as Prussian blue, but extremely powerful and transparent, and may be substituted for some of the uses of Prussian blue, as the latter is for indigo.

Indigo blue is of great body, and glazes and works well, both in oil and water; but its relative permanence as a dye has obtained for it a false character of extreme durability in painting, a quality in which it is very inferior, even to Prussian blue.

22. The **indigo plant** is not, in general appearance, unlike the lucerne of our fields. The seed is sown in drills, about 18 inches apart, and, in about two months, the plants begin to flower. They are then cut down, but shooting up again, give two or three crops in the same year. As many of the newly cut, fresh, and green plants as will loosely cover the bottom, are placed in a shallow wooden vat. Water is then let in to submerge the plants about three inches, while heavy wooden frames are put on top to prevent them from floating. Left in this state from fifteen to twenty hours, fermentation sets in, much gas is disengaged, and the water becomes a light green color. The green liquor is then run off into a second vat placed below the level of the first, in which, while the fermentation process

is being repeated upon a fresh supply of plants in the first vat, it is violently agitated by being beaten with poles, causing the grain to separate. The green matter suspended in the liquor then becomes blue and granular, the change being hastened by the addition of a little lime water. This operation sufficiently advanced, the contents of the vat are allowed to settle, when the intensely blue granular matter sinks to the bottom, leaving the upper layer of the liquor almost as clear as water. This is then run off almost to the bottom and the sediment drained into a third vat, where it awaits several additions from successive operations. A sufficient quantity having been accumulated in the third vat, it is permitted to subside and then thoroughly settle, the clean liquor being drawn off and the granular matter removed and filled into coarse bags hung up to drain. When sufficiently drained, the blue paste is filled into small boxes about three inches square and set to dry in the sun, which soon renders it fit for packing.

23. Ultramarine blue is a pigment obtained from the precious blue stone known as *lapis lazuli*, but its costliness places it outside the colors commonly used in house painting. Its beautiful shade, however, causes its name to be applied to several imitations or artificial ultramarines, of which the French and German are the most satisfactory.

Artificial ultramarine is prepared by fusing in closed crucibles a mixture of soda, silica, alum, and sulphur, and reheating the greenish product thus obtained until the blue pigment appears, when it may be removed and ground up for use.

24. Brunswick or celestial blue is made by precipitating the alumine from a solution of alum with carbonate of soda, washing the precipitate, and adding sulphate of baryta, sulphate of iron, yellow prussiate of potash, and some bichromate of potash. When dried, this mixture is known as Brunswick or celestial blue, but when the sulphate of baryta is left out, and the material not dried, it is called *damp blue*.

25. Cobalt blue is the name now appropriated to the modern improved blue pigment prepared with metallic cobalt, or its oxides, although it properly belongs to a class of pigments, including Saxon blue, Dutch ultramarine, Thenard's blue, Royal blue, Hungary blue, Smalt, Zaffre or enamel blue, and Dumont's blue. These differ principally in their degrees of purity and the nature of the earths with which they are compounded. The first is the finest cobalt blue, and may not improperly be called a blue lake, the color of which, like enamel blues, is brought out by fire. When well prepared, it is of a pure blue color, superior to all other blue pigments. It resists the action of strong light and acids, but its beauty declines by the action of time and impure air.

YELLOW PIGMENTS.

26. Yellow, bearing, as already stated, the same relation to light as blue does to shadow, is capable of reduction, through several shades, till it merges into a cream white, its color limit.

27. Naples yellow is composed of the salts of lead and antimony, owing its name to the fact that it is supposed to have been first obtained from a volcanic product of Mount Vesuvius, near Naples. It is a very opaque pigment. and, therefore, covers thoroughly the surface to which it is applied, but is not as brilliant as chrome yellow and is very difficult to grind.

28. Chrome yellow, one of the most durable of pigments, is obtained from the subchromate of lead. Frequently adulterated with gypsum, it is prepared by mixing diluted solutions of acetate or nitrate of lead and bichromate of potash.

29. King's yellow is the name of a very dangerous and unsatisfactory pigment obtained from arsenic. It is not very poisonous, but injurious to other colors when mixed with them. Least durable of all the yellow pigments, it is

known, also, under the names of yellow orpiment and Chinese yellow.

30. Yellow ocher is a natural clay, colored by oxide of iron, found abundantly in many parts of England. **Stone ocher** is a similar pigment, found in the form of balls embedded in the stone of the Cotswold Hills, England. It varies in tint from yellow to brown.

RED PIGMENTS.

31. Red is the second and intermediate of the primary colors, standing between yellow and blue, and in like intermediate relation, also, to white and black, or light and shade. It is also the second in harmonizing and contrasting with other colors, and in compounding black and all neutrals. Red is a color of double power in this respect, that, in union or connection with yellow, it becomes warm and advancing, but mixed or combined with blue, it becomes cool and retiring. Hence, it is preeminent among colors—the most positive of all—forming, with yellow, the secondary orange, and its near relatives, scarlet, etc.; and, with blue, the secondary purple, and its allies, crimson, etc. It gives some degree of warmth to all colors, but most to those which partake of yellow. It is the principal color in the tertiary russet; enters subordinately into the two other tertiaries, citrine and olive; goes largely into the composition of the various hues and shades of the semineutral, maroon, or chocolate, and its relatives, puce, murrey, morello, mordore, pompadour, etc., and, more or less, into browns, grays, and all broken colors. Tertiary and neutral colors are explained hereafter.

32. Vermilion is a sulphuret of mercury, which, previous to its being levigated, is called cinnabar. It is an ancient pigment, found both in a native state and produced artificially. The Chinese possess a native cinnabar so pure as to require grinding only to become very perfect vermilion. The Chinese are, besides, supposed to have a

process of manufacture unknown to us, whereby superior brilliancy is imparted to the color, and the beauty of the natural pigment enhanced.

Vermilion is artificially prepared by melting one part of sulphur and adding to it gradually five or six parts of mercury. The heat is maintained until the mixture swells up, and the vessel covered and removed from the heat's action. When the mixture is cold it is reduced to powder and sublimated in a closed vessel, placed in a furnace, so that the flames may play freely around it to one-half its height. The heat is gradually increased till the lower portion of the sublimating vessel becomes red hot; the cold sublimate, afterwards broken into pieces, ground in water to a fine powder, is passed through a sieve and dried.

Powder vermilion may thus be tested: Place a small quantity on a piece of paper laid on a hard surface, cover this with a card or other piece of paper, which rub with the thumb nail, the handle of a penknife, or other hard substance. If the vermilion be pure, it will, on the removal of the paper, present a smooth surface of the uniform original color, but, if adulterated with red lead, etc., it will appear orange or yellow.

33. Red lead is a very old pigment, formerly known as minium or saturnine red, confounded, by some old writers, with cinnabar. It is a deutoxide of lead, prepared by subjecting massicot to the heat of a furnace, with an expanded surface and free accession of air. It is of scarlet color and fine hue, warmer than common vermilion, bright, but not as vivid as the biodide of mercury though having the body and opacity of both pigments. It has been, even in name, confounded with vermilion, with which it was formerly the custom to mix it. When pure it is unaffected by light, but acids, white lead, or any oxide, or preparation of the metal, soon deprive it of color, while impure air will blacken and ultimately metallize it.

Red lead may be adulterated with colcothar, a sesquioxide of iron. It thus forms a powder without taste or smell,

insoluble in water, alcohol, or any essential oils. Red lead is often adulterated with brick dust, whose presence is easily detected. Heat the red lead in an iron crucible and treat with nitric acid diluted, whereby the red lead will be dissolved and the brick dust remain.

34. Light red is in reality a burnt ocher of russet orange hue, principally valued for its tints, when mixed with other pigments. The crimson light red is a brown ocher burned. The principal yellow ochers afford this color best; the brighter and better the ocher from which this pigment is prepared, the brighter will be the red, and the better the flesh tints it will afford with white. It is greatly used in figure and landscape painting.

35. Venetian Red or Scarlet Ocher.—True Venetian red is believed to be a native ocher, but the various pigments sold under this name are prepared from sulphate of iron. It is frequently, during manufacture, adulterated with sulphate of lime, but this process increases its bulk and improves its mixing qualities at the expense of depth of color.

36. Indian red is a ground ore hematite or peroxide of iron, brought, as its name indicates, from Bengal, India, but may, by calcining sulphate of iron, be artificially prepared. Its tints vary greatly, but the best are those of a rosy hue. This pigment, an anomalous red of a purple-russet hue, has good body and is valued, when fine, for the pure lake-like tone of its tint. In its crude state, it is a coarse powder full of hard and brilliant particles, of dark appearance, somewhat magnetic, and, on account of a chemical tendency to deepen under this treatment, is greatly improved by grinding and washing. It is, besides, very permanent, unaffected either by light, impure air, or mixture with other pigments. Defying the effects of time or fire, it remains an opaque color, covering its surface satisfactorily. Indian red is, sometimes, called Persian red.

37. Lakes.—The name *lake*, given to a series of red and other colored pigments, is derived from the East Indian

term *lac* or *lacca*, the material from which lakes were originally made. They are now usually prepared by precipitating colored tinctures of dyes upon alumine and other earths, etc. The lakes are, therefore, a class of pigments, numerous both with respect to variety of appellation and diversity of substance entering into their preparation. The coloring matter of common lake, also known as drop lake, is brazil wood, affording a very fugitive and unreliable color. Superior red lakes are prepared from lac, cochineal, and kermes, but the best from the root of *rubia tinctorum*, or madder plant.

38. Scarlet lake is one of a numerous lot of lakes made from cochineal, others being Florentine lake, Hamburg lake, Chinese lake, Roman lake, and carminated lake.

Cochineal consists of the bodies of female cochineal insects (*coccus cacti*) killed and dried by heat. This insect feeds on plants of the cactus family, particularly on one known in Mexico as the napal, nearly allied to the prickly pear. This insect is a small creature, a pound of cochineal containing, it is said, 70,000 dried bodies of cochineals. The male is of a deep red color, with white wings. The female, of a deep brown color, is wingless, covered with a white powder, the body being flat beneath and convex above.

Cochineal is of a deep red color which, treated with acids, becomes more or less of an orange tint, but if subjected to the influence of an alkali, turns to a violet color. Cochineal is the base of many red pigments, noted strictly for their glazing qualities.

39. Glazing is a term given to the method of spreading lakes and other transparent colors over a body color, previously applied. The effect is to add richness and depth to the under color, the transparent outer tint then receiving the name of glazing color.

40. Carmine is from kermes, the *coccus ilicis*, found on certain oaks in the Mediterranean. Although not generally used in house painting, this splendid color calls for notice. The name originally given to the finer tinctures of kermes

and cochineal now generally denotes any pigment resembling these in beauty, richness of color, and fineness of texture. Carmines produced from cochineal, by the agency of tin, are of fine powdery texture, velvety richness, and beautiful brightness of color. Carmine was first discovered by a Franciscan monk while preparing medicine containing cochineal. It began, in 1656, to be manufactured, and is undoubtedly the finest red known. One process for its preparation is to digest 1 pound of cochineal in 3 gallons of water for 15 minutes. Add 1 ounce of cream of tartar, heat gently for 10 minutes, and, after allowing impurities to settle, the clear liquid is placed in a glass pan, when the carmine is slowly deposited. After a time the liquid is drained off, and the carmine dried in the shade on a bright, warm day.

41. Yellow Lake.—There are several pigments of this denomination, varying in color and appearance, according to the coloring substances and the modes of preparation used. Usually in the form of drops, their colors are ordinarily bright yellow, very transparent, and not liable to change in an impure atmosphere—qualities of undoubted value.

42. Rose pink is a coarse kind of lake, produced by dyeing chalk or whiting with a decoction of brazil wood. It fades quickly, and is chiefly used for paper hangings, etc. Dutch pink is a similar substance, made from quercitron bark.

SECONDARY COLORS.

43. The mixing of any two of the primary colors produces a secondary color, and as there are but three primaries, there can be but three secondaries. The three primary colors, red, yellow, and blue, when mixed in pairs, form the three secondaries, as follows:

Red, combined with yellow, forms orange; while red, combined with blue, produces violet or purple. Yellow, combined with blue, gives us a green, while its other combinations with red, as well as the combinations of blue with red and yellow, are above described.

Orange, green, and violet or purple are, then, the secondary colors prepared by mixing as above, and may, in some cases, be obtained direct from the pigment itself. The combination of one secondary with any other secondary color, will produce a **tertiary** color.

ORANGE.

44. Orange, the first in relation to light of the secondary colors, is composed of yellow and red. Such a compound of red and yellow as will, in an equal quantity of either surface or intensity, neutralize a perfect blue, is justly termed a true and perfect orange. By *neutralize* is meant "offset" in intensity or prominence. The proportions of such a compound are five of perfect red to three of perfect yellow. When orange inclines to red, it takes the names of scarlet, poppy, coquilicot, etc. In gold color, etc., it leans towards yellow. In forming the tertiary citrine, it combines with green; and, with purple, constitutes the tertiary russet. With black, it also forms a series of warm semineutral colors, harmonizing in contrast and variety of tints with white. In nature it is effective, acting powerfully at a great distance, diminishing its sensibility in proportion to the strength of the light in which it is viewed. It is of the hue, and partakes of the vividness, of sunshine, as it does also of all the powers of its components, red and yellow.

This secondary is preeminently a warm color, being the even contrast or antagonist, in this respect—as it is also in color—of blue, to which the attribute of coolness peculiarly belongs; hence, it is discordant when standing alone with yellow or with red, unqualified by their proper contrasts. In the well known fruit of Aurantium, called orange from its golden hue, the fruit which gives this color its well adapted name, Nature has associated two primary colors with two primary flavors, seemingly analogous—a red and yellow compound color, with a sweet and acid compound flavor.

GREEN.

45. Green, which, in the general scale of colors and in relation to light and shade, occupies the middle station, is second among the secondary colors. Composed of the extreme primaries, yellow and blue, it is in hue most perfect, constituted in proportions of three of yellow to eight of blue of equal intensities. Such a green will, indeed, perfectly neutralize a perfect red in the proportions of eleven to five, either of space or power.

Of all compound colors, green is the most effective, distinct, and striking. So attractive in its constituents does it appear to the untutored eye, that, when first produced by the mixture of blue and yellow, green impresses the mind with surprise and delight. Mixed with orange, green converts it into the extreme tertiary, citrine. Mixed with purple, it produces the other extreme tertiary, olive. Hence its relations and accordances are more general, and its contrasts with other colors more agreeable, than those of any other. The beautiful verdure that it bestows throughout all nature affords the most welcome repose to the eye, for it emphasizes the beauties in harmonizing with the colors of the flowers for which it forms a background. Greens produced directly of copper, arsenic, etc. are more durable than those composed of blue and yellow.

46. Chrome greens are compound pigments of which chrome yellow is the principal coloring substance. They are also called Brunswick green, etc., which are compounds of chromate of lead with Prussian and other blue colors, beautiful to look upon, suitable, too, for certain mechanical purposes, but unfit for fine art. There is, however, one true chrome, or native green, the coloring matter of which, being the pure oxide of chromium, free from lead, is enduring against the action of sunlight and of impure air. Of various degrees of transparency and opacity, and of several hues more or less warm or cool, it affords pure, natural, and durable tints. True chrome greens neither inflict upon nor receive injury from other pigments, and are eligible for either water

or oil painting, in the latter case, drying well as a rule. They likewise afford valuable colors in enamel painting.

47. Brunswick green is one of a large class of pigments, grouped under the name of copper greens, and comprehending verdigris, verdite, malachite, mineral green, Schweinfurt or Vienna green, green bice, Scheele's green, emerald green, green lake, mountain green, African green, French green, marine green, Olympian green, etc., some of which call for special mention.

48. Verdigris, or *viride aeris*, is of two kinds, common or impure, and crystallized or, more properly, refined verdigris. Both are acetates of copper of bright color, inclining to blue, and are the least permanent of the copper greens, soon fading and becoming white by the action of light, particularly in water colors, and ultimately, through dampness and foul air, turning black.

49. Emerald green is the name of a copper green of an earthy hue. The most vivid of this class of colors being rather opaque and powerfully reflective of light, it appears to be the most durable pigment of its class. Not common in nature, its hue is well suited for brilliant works. The only true emerald green is that of chromium with which nature gives the green color to the emerald. Emerald green is, for purposes of commerce, made of verdigris mixed with a solution of arsenious acid. It is brilliant in color, very poisonous, and difficult to grind.

50. Scheele's green is a compound oxide of copper and arsenic, or arsenite of copper, named after the justly celebrated chemist who discovered it. Of a beautiful, light, warm green color, opaque, permanent in itself and in tint—when mixed with white lead, it is to be cautiously used with Naples yellow, which soon destroys it. Schweinfurt green and Vienna green are the names of pigments similar to that just given. Less affected by damp and impure air, these pigments are, therefore, more eligible than simple copper greens. All these greens are, however, very poisonous.

51. Several other greens are made from copper, such as Brighton green, malachite, mountain green, marine green, Saxon, African, French, patent green, etc. Mineral green is the commercial name of green lakes, prepared from sulphate of copper. It is a good, durable color for house painting, made from bibasic carbonate of copper.

PURPLE.

52. Purple, the third and last of the secondary colors, is, as already stated, composed of red and blue, in the proportion of five of the former to eight of the latter. This constitutes a perfect purple, one of such hue as will best contrast with and neutralize a perfect yellow, in the proportions of thirteen to three, either of surface or intensity. It forms, when mixed with the co-secondary color, green, the tertiary color, olive; and when mixed with the remaining secondary color, orange, constitutes, in like manner, the tertiary color, russet. The coolest of the three secondary colors, it is nearest to black in respect to shade, in which regard, as well as in its quality of never being a warm color, it also resembles blue. Purple partakes, in other respects, of the properties of blue, for blue is its governing tint. To the eye, purple is a most retiring color, reflecting little light and declining rapidly in power, in proportion to the distance at which it is viewed. It also recedes in a declining light, wherein it proves itself the most retiring of positive colors.

Purple is, next to green, the most pleasing of the consonant colors. As much, perhaps, from its rareness in a pure state, as from its individual beauty, it has long been celebrated as a princely and imperial color. Purple, when inclining to red, takes the name of crimson. Indicative of other shades of purple are the names violet, lilac, etc. Purple may be made by the admixture of ultramarine blue and vermilion, or of Prussian blue and lake, with varied proportions of white—that pigment required to impart a blue tendency predominating. With increased additions of white, the various tints of lavender, lilac, etc. are produced.

SEMINEUTRAL COLORS.

53. As color descends according to the regular scale from white, and therefore properly terminates with olive, neutral black would here naturally end the series. Practically, however, every colored pigment of any class whatever combines with black. Hence arises a new series in the scale of colored compounds, having black for its basis, distinguished by the term semineutral and divided into three classes, brown, maroon, and gray. Inferior as they are, in point of color, the semineutrals comprehend a great proportion of our permanent pigments, being, so to speak, black tints or shades.

54. **Umber** is the name of a brown pigment obtained through the agency of oxide of iron from naturally colored clays, some coming from Turkey, and some again from Umbria, in Italy, whence the color takes its appellation. In its natural state it is usually designated as **raw umber,** while **burnt umber,** a pigment of darker color than the preceding, is obtained by calcining raw umber at a low temperature.

55. **Vandyke brown,** hardly less celebrated than the great painter whose name it bears, is a species of bog earth of a fine, deep, semitransparent brown color. The pigment much used and esteemed by Vandyke came, it is said, from Cassel, a town in Prussia. The Vandyke browns in use at present appear to be terrene pigments of a like kind, purified by grinding and washing.

56. **Raw sienna** appears to be an iron ore, considered as a crude natural yellow lake. Valuable, very absorbent, and firm in substance, it presents, when broken, a glossy surface. It becomes, by burning, a deep orange, more transparent and quicker in drying, and is a valuable color in graining.

57. **Sepia** is a brown pigment originally obtained from the excrescence of the cuttlefish, sometimes called the

inkfish, on account of its affording this dark liquid, used by the ancients both as an ink and pigment. Sepia, though brought originally from the Adriatic, may be obtained from the fish of our own coasts. Of a powerful dusky brown color and fine texture, it works admirably in water, combines cordially with other pigments, and proves very permanent in results. It is mainly used as a water color on account of its reluctance to dry in oils.

58. Asphalt, or **mastic,** a fireproof and waterproof pigment, is obtained in natural formations, such as the great asphalt lake in Trinidad. Used more as a varnish than a paint, it is, when mixed for use, dissolved with resin in tar oil, in the proportion of about ½ pound each of asphalt and resin to 2 pounds of oil, then kept hot till the dissolution is complete.

59. These various pigments may, according to uses and characteristics, be classified:

1. Those more or less transparent and fit for graining and finishing are: all blacks (except mineral blacks), umbers, chrome greens, cadmium yellow, raw and burnt sienna, ocher, French ultramarine, Mars orange, and brown sepia.
2. Those little, if at all, affected by heat or fire—the whites and the ochers, in natural clays.
3. Those for fresco or distemper work are the whites made from sulphate of baryta or carbonate or sulphate of lime, all the ochers, the reds, blues, browns, and blacks.
4. Those more or less injured by damp and impure air, especially sulphureted hydrogen, and are unfit to use in distemper, are white lead, all the yellows, except the ochers, red lead, Chinese and Persian lead, Prussian and cobalt blues, orange salts of lead, and all greens.
5. Those which fade or are affected by strong light—all vegetable colors, including the yellows, Prussian blue, indigo, the peaty browns to a considerable extent, and, in less degree, the madders.

VEHICLES.

OILS AND DRIERS.

CHARACTER AND PURPOSES OF OILS.

60. Oil is one of the fluid mediums in which a pigment is suspended to enable the painter to spread it properly and cause it to adhere when dry. It is termed the *vehicle*, because it serves to carry the pigment evenly over the surface to which it is applied. The vehicle is usually combined with some other medium, or subjected to some special preparation, to give it the drying qualities it seldom in itself possesses. The medium so added is called a *drier*, as will be explained hereafter, and is varied in material and quantity, according to the character of the oil with which it is mixed.

LINSEED OIL.

61. The oil most generally used by the house painter is obtained by the compression of flaxseed. This oil varies greatly in quality, as well with reference to the seed from which it is extracted, as in respect of age and consequent clearness. When a large quantity is, for six months or more, kept stored, an accumulation of refuse forms at the bottom and cannot be used, save in mixing coarse paint for outside work. Linseed oil is, from its cheapness, the only oil in common use for house painting, and may, under proper management, answer for every kind of work. The marked defects in linseed oil are its brown color and its tardiness in drying. These defects may, however, be greatly diminished, if not entirely removed, by keeping the oil for a length of time before use. It then becomes a good vehicle for color without any mixture. It is generally, nevertheless, used with a proper drier, and it never by itself becomes sufficiently pure to use with white or other light tints, without imparting a brown color. The drying of raw linseed oil may be

accelerated by adding about 1 pound of white lead to every gallon of oil, and allowing it to settle for at least a week. Not only is the color of the oil thus improved, but the lead may be afterwards used for ordinary work.

Several methods have been contrived for bleaching and purifying linseed oil, but there is no known process for entirely preventing discoloration after drying.

One method for the purification of linseed oil is to place the oil in a bottle or jar, and drop into it some powdered whiting. Then stir or shake up the mixture, allowing it afterwards to stand for a time in a warm oven. The whiting will very soon carry down all color and impurity, and form a precipitate at the bottom. The refined oil at the top may then be drawn off. In the rare instances wherein the least yellowness in the oil might prove injurious, nut or poppy oil may, with advantage, be used, but linseed oil, for general purposes, is to be preferred.

62. Boiled linseed oil, usually designated **boiled oil,** is prepared by heating raw oil with certain driers. The drying qualities of the raw oil are greatly improved by the mere process of boiling, but when such substances as those below mentioned are added, this improvement is greatly enhanced. Dark drying oil may be made of these ingredients: 1 gallon of linseed oil; 1 pound of red lead; 1 pound of umber; 1 pound of litharge. Note, however, that, after boiling, the oil becomes much thicker, and, being too fat and likely to clog, cannot be used for purposes of grinding.

In the process here in question the linseed oil is heated to about 200° F. When it looks brown and the scum is all burned off, the other substances are added; the whole is then brought up to 400° F., and, for two or three hours, kept at that temperature. The oil is then drawn off, and the albuminous matter allowed to deposit, after which it is ready for use. The umber is added simply to give the oil a dark color.

Boiled oil to be used with zinc paint must be free from oxides of lead. About 5 per cent. by weight of powdered

peroxide of manganese is boiled in the oil, for five or six hours, the mixture allowed to cool, and then filtered.

Pale drying oil may consist of 1 gallon of linseed oil, mixed with about 7 pounds of litharge or acetate of lead, raised to a moderate temperature.

Drying oil for common work may be made by boiling 1½ pounds red lead in a gallon of raw linseed oil, and allowing the mixture to settle.

Linseed oil is, sometimes, boiled with litharge to cause it to dry quickly, but, when thus treated, is unfit for the better classes of work. The quality of linseed oil may be determined by looking through a vial filled with it and turned towards the light. If poor in quality, the oil tends towards opacity, appears turbid or milky, while its taste is strong and rancid. Good fresh oil should be, in appearance, clear and pale; in taste, sweet, and emit little or no odor.

NUT AND POPPY OIL.

63. Nut oil, an almost colorless, transparent oil, is expressed from the walnut. It dries more rapidly than linseed oil, and is, owing to its lack of color, used for white and other light paints. In the commoner grades of work, its cheapness commends it to use.

64. Poppy oil is colorless, and, in some instances, used for delicate work, where the time required for drying is not limited. For strength and durability it stands second to linseed oil. Poppy oil is, in some old books, spoken of as oil of pinks, and oil of carnations.

TURPENTINE.

65. Turpentine is the oleoresin exuding from any one of several coniferous trees; also the semifluid resin of the terebinth or turpentine tree—*Pistacia Terebinthus.*

The principal varieties of turpentine are the following:

Aleppo turpentine, from the Aleppo pine.

American turpentine, from the long-leaved pine,

Bordeaux turpentine, from the seaside pine.
Canadian turpentine, from the balsam fir.
Carolina turpentine, from the long-leaved pine.
Carpathian turpentine, from the Swiss pine.
Chio or Chian turpentine, from the turpentine tree.
German turpentine, from the Scotch pine.
Hungarian turpentine, from the Mugho pine.
Strasburg turpentine, from the European silver fir.
Syrian turpentine, from the pistachio-nut tree.
Venice turpentine, from the European larch.
White turpentine, from the long-leaved pine.

66. The process of saving and collecting the liquid is, in nearly all cases, similar. A hollow is cut in the tree a few inches from the ground, and bark, for about 18 inches above it, removed. The turpentine then trickles down into vessels. The incisions are made about the end of March and the turpentine continues to run throughout the vegetative season. These turpentines have in general character much in common, being oleoresins, varying slightly in color, consistency, and smell.

Imported in barrels of 2 or 2½ hundredweight, turpentine has the appearance and consistency of honey. The residuum, after the distillation of the oil or spirits of turpentine, is the common resin, or rosin, of commerce.

67. **Oil of turpentine** is obtained by distilling with water, in an ordinary copper still, turpentine previously melted and strained. The distilled product is colorless, limpid, very fluid, and of a very peculiar smell. The rectified oil, improperly called **spirits of turpentine,** is preferable on account of being thinner and more free from resin. When colored by heat or otherwise, oil of turpentine may be bleached by agitating some lime powder in it. The ordinary use of this oil is to thin oil paints, to flatten white and other colors, or to remove superfluous color in graining. It prevents paint, however, from bearing out, and when used alone, will not fix the paint on the surface to which it is applied.

DRIERS.

COMPOSITION AND CLASSIFICATION OF DRIERS.

68. **Driers** are substances added to paint in order to cause the oil to thicken and solidify more rapidly. The drying of linseed oil is caused by the absorption of oxygen, and there is little doubt that driers usually act simply as carriers of oxygen to the oil, a very small quantity yielding quite extensive results. The best driers, therefore, are those containing a large proportion of oxygen, such as litharge, acetate of lead, red lead, sulphate of zinc, verdigris, etc., which, added to the oils, improve their drying qualities by causing the more rapid absorption of oxygen. These driers are ground up in oil and mixed in small quantities with the suspended pigment. Some colors will not dry without driers, but remain tacky, and thereby exposed to much injury, through the accumulation of dust and the degeneration of the tints.

69. The following is a list of driers, each of which is suited to some particular quality or color of paint:

Red lead makes a good cheap drier, but can, of course, be used only in situations or in paints where its color is unobjectionable.

Sugar of lead (acetate of lead), ground in oil, is the best but most expensive of all driers, and is, like copperas (sulphate of iron) and white vitriol (sulphate of zinc), used as a drier, especially for light tints.

Litharge, or oxide of lead, the drier most commonly used, is produced in the oxidation of lead containing silver. It can be procured, on a small scale, by scraping off the dross which forms on molten lead, exposed to a current of air.

Massicot is a superior kind of litharge, produced by heating lead to a degree insufficient to fuse the oxide.

Oxide of manganese, though not as rapid as litharge or massicot, is quick in effect, but, being of a very dark shade, is seldom used except for the deep colors.

Sulphate of manganese is the best drier for zinc white,

about 6 or 8 ounces only being used for 1 hundredweight of ground zinc paint. The manganese should be mixed with a small quantity of the paint first, and then added to the bulk. If great care be not taken in mixing the drier, the work will be spotted.

Japanner's gold size (acetate of copper) is for some uses an excellent drier, but care must be taken not to use too much or it will make the paint brittle and cause it to crack.

Patent driers containing oxidizing agents, such as acetate of lead, litharge, etc., are ground and mixed in oil, ready for immediate use. Some of the inferior descriptions, depending for their drying qualities upon lime, should be avoided.

Térebene is a powerful drier, used as a substitute for patent driers, and mixed in the proportion of 1 ounce of terebene to 1 pound of paint, will dry in about half an hour.

Xerotine siccative is a species of terebene, but differs from it, in that when mixed with oil, the mixture does not become cloudy. In the use of any of the above driers, the following should be observed: First, not to use them unnecessarily with pigments which dry well in oil color; second, not to employ them in excess, which not only retards the drying, but injures, if it does not destroy, the paint; third, not to add them to the color until ready for use; fourth, not to use more than one kind of drier to the same lot of paint.

VARNISHES.

70. Varnish is a solution of certain gums or resins in alcohol, turpentine, linseed oil, or the like, and is applied to produce a hard, shining, transparent coat on the surface. The oil dries, but the alcohol and turpentine evaporate, leaving, in either case, the fine transparent film of resin over the surface varnished.

To estimate the quality of a varnish, the following points are to be considered: (1) quickness in drying; (2) hardness of film or coating; (3) toughness of film; (4) amount of gloss; (5) permanence of gloss; (6) durability on exposure to weather.

The value of a varnish depends almost entirely upon that of its constituents, but much care and skill are demanded in mixing and boiling the ingredients. Varnish is used to give brilliancy to painted surfaces and to protect them from the action of the atmosphere or from any slight friction. Varnish is often applied to plain unpainted wood surfaces in the roofs, joinery, and fittings of houses, to intensify and brighten the ornamental appearance of the grain. It is also applied to painted and papered walls. It is, in the former case, sometimes flatted, to give a dead appearance, similar to that of a flatted coat of paint.

The resins from which varnishes are most usually made are, in general appearance and characteristics, very much the same, but differ in name, according to the tree or shrub from which they are gathered, and, in most cases, give their names to the varnish into which they enter. Thus, we have copal varnish, dammar varnish, mastic varnish, shellac varnish, etc., each of which is made from the gum its name indicates. Before considering the various applications of these varnishes, let it here be understood that they are all more or less interchangeable for all purposes, the specific applications being governed as well by the quality of work required as by the cost of the varnish.

71. Copal varnish is thus prepared: In an iron pot, over a slow fire, eight parts of powdered copal gum are melted with two parts of balsam copaiba, previously warmed. The melted gums are then removed from the fire and reduced to the proper working consistency, by the addition of about 10 parts of oil of turpentine.

Gum copal is more soluble in turpentine, when the gum is powdered and melted, and then permitted to stand for some time in a loosely covered vessel. The varnish is, under this method, best made with 24 parts of powdered copal, 40 parts turpentine, and 1 part camphor.

72. White copal varnish is prepared by dissolving 8 parts of copal and 1 part camphor in 6 parts of white drying oil and 4 parts of the essential oil of turpentine. The

powdered copal is mixed with the camphor and drying oil, then heated, the turpentine added, and the varnish strained.

73. Gum mastic affords a base for a varnish nearly as hard as copal varnish, but better adapted to certain classes of work, where subsequent rubbing is not required. It is particularly useful to the artist in varnishing pictures, and is incidentally used, for the same purpose, by the fresco painter, when his works are executed in oils.

Mastic varnish is prepared as follows: A vessel containing 10 ounces of gum mastic and 1 pint of turpentine is heated over a sand bath until the mastic is completely dissolved. The varnish is then strained through a sieve and is ready for use unless too thick, in which case its consistency may be reduced by the addition of a sufficient quantity of spirits of turpentine.

74. Magilp is the term applied to the composition resulting from a mixture of equal portions of turpentine and pale dry oil, of linseed drying oil and mastic varnish, of simple linseed oil and sugar of lead, or of boiled oil, mastic varnish, and sugar of lead combined. These ingredients gelatinize when mixed with oil colors and give them a certain amount of body and pulpy transparency.

75. Varnish resisting boiling water and well adapted to the finishing of floors, or other surfaces likely to meet with hard wear, may be made of: linseed oil $\frac{1}{2}$ pound, amber 1 pound, pulverized litharge 5 ounces, powdered white lead 5 ounces, minium 5 ounces. Boil the linseed oil in a copper vessel, suspend in it the litharge and minium in a small bag, which must not, however, touch the bottom of the vessel; continue the ebullition until the oil has acquired a deep brown color; then take out the bag and put in a clove of garlic; this to be repeated seven or eight times during the continuance of the boiling. Before the amber is added to the oil, it is to be mixed with 2 ounces of linseed oil and melted over a hot fire; when the mass is fluid, it is to be poured into the linseed oil. The mixture is again boiled and stirred continuously for two or three minutes. It is afterwards

filtered and preserved in a bottle well corked. This varnish is to be used only on wood previously well polished and covered with a thin coat of soot and oil of turpentine. When this coat is dry, some of the varnish is applied with a sponge, care being taken that it is equally distributed in every part. This operation is to be four times repeated, and attention always paid that one coat be well dried before the application of another. After the last coat of varnish, the wood is thoroughly dried and afterwards polished.

76. Soft resins are sometimes substituted for mastic, and inferior hard resins also employed in place of copal, in the composition of varnishes known as copal varnishes. Copal is of difficult solution in turpentine and linseed oil, both of which enter into the composition of the ordinary copal varnishes, employed by the coach painter, affording the best varnishes used by the house painter and grainer. Combined with linseed oil and oil of turpentine, copal varnish affords a vehicle superior in texture, strength, and durability to mastic or magilp, though in application a less attractive instrument and more difficult of management.

As copal swells while dissolving, its solutions and varnishes contract and consequently split in drying, making unsightly fissures, against which linseed oil is the essential preventative. The mixture of copal varnish and linseed oil is best effected through the medium of oil of turpentine, heat being for this purpose sometimes requisite.

77. White hard spirit varnish is a composition used very largely for japanned work, and may be prepared by dissolving in 3 pints of rectified spirits (65 over proof) one pound of gum sandarac, and adding to the solution 6 ounces of turpentine; or, if sandarac cannot be readily obtained, the varnish may be made of 4 ounces of gum mastic and ½ pound of gum juniper, dissolved in 4 pints of rectified spirits, adding 1 ounce of turpentine. When the varnish is to be used on metal work, or when polishing is necessary, 2 ounces of mastic in tears, 8 ounces of sandarac, and 1 ounce of gum

elemi are dissolved in 4 ounces of turpentine and 1 quart of rectified spirits (65 over proof).

78. A cheap varnish, suitable for ordinary work, can thus be made: Place 3 pounds of powdered resin in a vessel, add $2\frac{1}{2}$ pints of oil of turpentine; shake well and allow the mixture to stand for a day or two, meanwhile shaking it occasionally. Then add 5 quarts of boiled oil, shake the whole and allow it to stand in a warm room till clear. The clear portion is then poured off for use, and may be reduced in consistency by the addition of turpentine. This varnish is intended for protecting surfaces against the effects of exposure to the atmosphere, and has been used with advantage, where no direct impairment by wear is involved. Unable to resist the effect of constant wear and less brilliant than other varnishes, this ordinary work varnish is unfit for fine results or for work subject to continual usage.

79. White lac varnish is prepared by dissolving in alcohol or spirits of wine the lac resin of India, chemically deprived of all coloring matter and purified from gluten, wax, and other extraneous substances with which it is naturally combined. The varnish it affords, without this purifying process, is opaque, dark in color like the japans and lacquers of the East, but when thus purified is brilliantly transparent, very hard, and nearly colorless. This being a spirit varnish, requires a warm temperature, helpful, indeed, to all varnishes; and enjoys the valued distinction of drying rapidly.

White lac varnish being somewhat costly, its place is often filled, in ordinary work, by the common **white shellac varnish,** consisting of the softer resins dissolved in alcohol with shellac. To prepare it, dissolve 2 ounces mastic, $1\frac{1}{2}$ pounds shellac, 4 ounces seed lac, and 4 ounces sandarac in one gallon of rectified spirits of wine. Gum, benzoin, dragon's blood, turmeric, or other coloring matters may be added as required, but the natural color is nearly white.

80. Spirit varnishes or lacquers are made with softer gums, such as lac and sandarac, dissolved in spirits of wine

or pyroligneous spirit. They dry more rapidly, become harder and more brilliant than turpentine varnishes, but being apt to split and scale off, are used for cabinet and other work not exposed to the weather.

81. Furniture Varnishes.—One of the simplest of these varnishes may be prepared by dissolving 1½ pounds of shellac in 1 gallon of naphtha, or dissolving 12 ounces of shellac and 3 ounces of copal, or an equivalent of copal varnish, in 1 gallon of naphtha.

Table varnish is a fine quality of furniture varnish, and is prepared as follows: 1 pound dammar is dissolved in 2 pounds of spirits of turpentine; 200 grains of camphor are then added, and the mixture permitted to stand twenty-four hours, when the clear portion is poured off, fit for immediate use.

White furniture varnish: Dissolve 6 ounces of white wax in 1 pint of oil of turpentine by gentle heat; or white wax 6 parts, petroleum 48. It must be applied to a warm surface, which is then allowed to cool, and afterwards polished by rubbing with a coarse cloth.

82. Dark varnish for light woodwork: Shellac, 16 parts; gum sandarac, 32; gum mastic, 8; gum elemi, 8; dragon's blood, 4; anatto, 1; white turpentine, 16; alcohol, 256. Dilute with alcohol as may be required.

83. Mahogany varnish: Gum sandarac, 2 ounces; shellac, 1 ounce; gum benjamin, ½ ounce; Venice turpentine, 1 ounce; spirits of wine, 1 pint. Color red with dragon's blood, or yellow with saffron. Place the vessel with these ingredients in a warm spot, until the gum has dissolved, then strain for use.

84. Turpentine varnish is not very durable, will not stand washing, and should be used only for varnishing wall papers. It may be prepared by dissolving, in 1 pint of oil of turpentine, 10 ounces clear powdered resin; which is then boiled for half an hour, or until the resin is dissolved. When the mixture has cooled it is ready for use. Another

paper varnish consists of 4 pounds of dammar, dissolved in 1 gallon of turpentine, with moderate agitation or gentle heat. It is suitable for paper hanging and like purposes.

85. Water varnish consists of lac dissolved in hot water, with just so much of ammonia, borax, potash, or soda, as will dissolve the lac. The solution makes a varnish that will just bear washing. Alkalis darken the color of the lac.

STAINS.

COMPOSITION AND CLASSIFICATION OF VARIOUS WOOD STAINS.

86. Stains are liquid preparations of different tints, applied to the carefully prepared surface of the cheaper woods, such as poplar, pine, etc., in order to give them the appearance of the more rare and expensive woods, such as rosewood, mahogany, walnut, etc. The process of staining consists, in the main, of laying on the stains in the form of mere washes, so as to change the shade of one wood to that of another which, in its natural grain, it resembles. The stain is applied with a sponge or large brush, the wood having been previously well rubbed with glass paper, and the dust resulting carefully removed. The stain should be sparingly applied and well rubbed in, the desired depth of color being obtained by several washes rather than by a dark and heavy one.

The preliminary operation of sizing requires some care. To be rapidly and evenly spread, the size must be applied with a large brush, and should be quite hot and very thin. Where convenient, the wood should likewise be warmed.

In the case of hard woods, the tinting colors should be added to the filler before staining.

87. Stains suitable for different kinds of woods may be prepared as follows:

Mahogany stain: A thin mixture of burnt sienna, ground

in vinegar, may be used, and grained and shaded while wet with the same, thickened with more sienna.

Black walnut: The same as the preceding, but using burnt umber for burnt sienna.

Walnut stain: Boil together, for ten minutes, 1 quart of water, 1½ ounces washing soda, 2½ ounces Vandyke brown, ¼ ounce bichromate of potash.

Oak stain: Dissolve 2 ounces of American potash, 2 ounces of pearlash in 1 quart of water; keep corked and for lighter tints dilute with water.

Black stain: Boil ½ pound logwood in 2 quarts of water; add 1½ ounces verdigris, and ½ ounce copperas; strain; put in ½ pound rusty filings; apply two coats.

Red stain: Use a solution of dragon's blood in spirits of wine.

CREOSOTE STAINS.

WOOD PRESERVATION.

88. Creosote is the basis of several valuable preparations for preventing rot in wood, and is, in the form of stains, assuming importance in the builder's art, as a substitute for paint. The softer kinds of wood, unless thoroughly seasoned, contain considerable sap, which, if not in some way expelled or neutralized, causes rapid decay. In the application of creosote to the wood, usually by dipping or with a brush, it is quickly absorbed into the pores, counteracts the chemical changes in the sap, and thereby indefinitely insures the durability of the wood. It also prevents dry rot as well as the ravages of wood-boring insects. The valuable qualities of creosote as a preservative of railroad ties, and timber under water, have long been recognized. The great advantage of creosote over paint is that the former, while entering closely into the structure of the wood, permits the evaporation of any moisture. Paint, on the contrary, has no preservative qualities in itself, merely forming a coating impervious to air and water, so that if the

wood has not been completely seasoned before painting, the imprisoned moisture will, in time, produce decay.

Creosote stains are now much used instead of paint on parts of buildings much subjected to wet, especially shingles and sidings. The cheapness of such stains, both in material and cost of application, is a factor of considerable importance. The cost of even the very best qualities does not exceed probably one-half that of paint, and as any person can do the work quite rapidly and with good effect, the labor of applying it is also much less than that involved in the process of painting. The saving in time is due to the thin character of the stain, which dries quickly and consequently permits the completion of more work, in a given time, than painting can allow.

From an artistic point of view, the superiority of creosote stains over paint is, even to superficial observers, apparent. Paint is a liquid veneer completely covering the wood and replacing the grainy surface with its own glossy monotony. It is proper to paint all smooth-planed wood in which utility and not artistic effect is of first importance. But when regard is had for artistic effect, paint, let it be noted, gives crude results, entirely masking the grain of the wood—one of the chief beauties of shingled roofs and side walls. Paint gradually becomes oxidized, and growing darker with age, splits and scales off, presenting a shabby and unpleasant appearance. To obviate this result, even the best paint must be renewed every three or four years, while many of the cheaper paints will hardly last two years without freshening.

Creosote stains are transparent and, instead of hiding, render the grain of the wood more prominent. For example, on a roof the surface texture of each shingle is different, and each, if creosoted, retains this characteristic, but if painted loses it entirely. As creosote stains enter into the structure of wood, they cannot split or peel, and as the color gradually disappears—for all colors will fade in strong sunlight—it becomes, in tone, softer and more delicate, producing the antique effect, by so many admired.

One of the principal virtues of creosote stains is that they

never turn black—a conspicuous fault of other stains and many paints. Work so treated can, therefore, be perfectly renewed with one coat of stain—an impossibility with a stain that turns black. The color effects of creosote stains are soft, warm, and rich, harmonizing perfectly with nature's tints, and seem to improve rather than deteriorate with age. Stains are as durable as the best paint—far more, indeed, than the inferior kinds—and, when properly applied to dry wood, quite as efficient as paint in preserving qualities.

Creosote diminishes, while paint in some cases tends to augment, the inflammability of wood. For use over weather-worn paint, the darker, heavier stains are to be preferred, yielding, in this respect, satisfactory results. Light stains should not, in fact, be applied over a dark paint. On newly painted work the use of stains cannot be recommended, because, where the wood is so covered, its absorbent quality is lost, and a stain effect impossible.

Paint may, however, be laid as well over a creosote stain as if applied to new wood. For this reason, a stain makes an admirable primer of smooth surfaces on which paint is to be subsequently laid, as it fills the wood and has preserving properties not to be found with common primers. Paint used over a creosote-stain priming coat will never mildew.

89. Clapboard sidings, as well as shingles, are susceptible of rich and delicate treatment with creosote stain, and at much less cost than painting involves. As a rough surface takes the stain better than a smooth one, sawed clapboards should be laid rough side out. When so treated they show a deep, rich color effect, almost equal to that of shingles. Fences, sheds, and other outbuildings may be stained at from one-quarter to one-half the cost of painting, besides being more effectually preserved from decay than if painted. The cheaper stains are very desirable for the insides of stables, coops, cattle sheds, etc., where the powerful antiseptic properties of creosote are of great value in destroying parasites and preventing disease.

When rain water from roofs is collected in a cistern, and

used for domestic purposes, care should be taken, if creosote stain is used, to prepare the stain so that it will quickly dry after application. The reason of this is that creosote, while uninjurious, is unpleasant to the taste; but upon drying rapidly will, after the first few rains, leave no foreign taste in the water. In fact, whether paint or stain is used on a roof surface, the first two or three rains should not be, on any account, collected, because, in the case of paint, the superfluous color is washed off and contaminates the water, while creosote affects its taste.

To bricks that are off-color, and in need of an even tone, any of the red stains may, with success, be applied. For this purpose they are, indeed, much used, and always with good results; the fact that they cannot crack or peel, being of great importance. One coat of the same color will usually, whenever needed, renew the stains; two coats, however, will, if a change of color is required, éffect the purpose. In restaining, a shade lighter than the result desired should be used, for the stains, being transparent, come out darker on old work than on new wood.

90. The stains may be purchased, ready for use, in any size package required, from a 1-gallon can to a 50-gallon barrel. They do not require thinning and may be applied either with a brush after the shingles are laid, or the latter may be dipped in the stain, before being laid. The advantages of dipping are that the shingles are more fully impregnated with creosote and consequently more thoroughly preserved, and when, in the course of time, they shrink, no untreated wood will show through the splits. Brush coating is, however, much the cheaper method. But even where the dipping method is used, it is advantageous to apply a brush coat after the shingles are laid, as it renders the color more permanent and yields a more uniform effect, covering raw edges where the shingles have been cut to fit corners, window frames, etc. In the brush treatment, two coats should always be applied, such work being far more lasting than if but a single coat is laid. That the color

effect may be uniform and permanent, care should be taken before using the stains, that they are so thoroughly stirred as to bring all the coloring matter into suspension. If the creosote be in a can, the stirring may be done through the opening in the top, but if in a barrel or keg, the head must be removed and the stain stirred every time a pot or tubful is taken out.

FIG. 1.

In dipping shingles, it is economy to fasten on the edge of the dipping tub, a brush on which to wipe each shingle as it is withdrawn, as shown in Fig. 1. This saves stain and hastens the drying. The shingles should not be soaked, but simply dipped in the stain, then removed as quickly as possible, and thrown in a loose pile, which a free circulation of air passing through, will speedily dry. One man can dip 7,000 per day. One gallon will cover 150 square feet of surface with one, or 100 square feet of surface with two coats. Dipping a thousand shingles requires $2\frac{1}{2}$ to $2\frac{3}{4}$ gallons, but the dipping and brushing of the same number of shingles demand 3 gallons. Two-thirds only of the length of the shingle need be dipped.

91. Creosote bleaching oil is used for producing a silver-gray effect on shingles. This material, at the time of its application, colors the wood to a slight degree only; a few months' exposure to the weather, however, bleaches the surface of the shingles to the beautiful silken silver gray, sometimes seen and admired on ancient seaside edifices. This charming color improves with age, and never calls for renewal, while the creosote preserves the wood, preventing mildew and the consequent blackening of the shingles. The creosote bleaching oil should be used on new work only. Its covering capacity is about one-fifth less than that of the ordinary stains.

METHODS EMPLOYED IN HOUSE PAINTING.

TOOLS USED BY PAINTERS.

GRINDING TOOLS.

92. The pigments described in the preceding pages are received from the manufacturer in the form of powder, and must be mixed or ground with oil to prepare them for use. This work is usually done in a color mill, where the pigments are ground in large quantities by manufacturers, from whom they may be purchased in the form of a thick paste; but where the painter prefers to mix his own colors, he may do so by grinding them on a color slab with a **muller,** such as is shown in Fig. 2. This consists of a semiellipsoidal stone, about four inches broad across the flat base, and sufficiently high to permit it to be grasped by both hands. Mullers smaller than this are likely to become rounded on the flat surface from unequal pressure, and in this condition are practically useless. The color slab is a flat piece of porphyry or other close-grained stone, upon which the pigment is placed preparatory to grinding.

FIG. 2.

93. Grinding is accomplished by mixing the powdered pigment with a sufficient quantity of linseed oil to form a thick paste, and grinding it under the muller by moving the latter backwards and forwards under pressure, lifting the advancing edge sufficiently, at each stroke, to cover the pigment which has been squeezed out from under. The pasty color must be frequently scraped up from the edges of the slab and deposited in the center to come under the strokes of the muller; this is usually done with a thin blade called the **palette knife,** shown in Fig. 3. This consists of a very

flexible steel blade, with dull edges and a rounded end, set into a hard wood handle. There are several sizes, varying from four to twelve inches in length, but the larger ones are usually termed **stone knives,** as they are never used for any other purpose than mixing the pigment and oil for the slab, while the palette knife is also used for mixing colors on the palette as described hereafter. After sufficient color has been ground on the slab, it is scraped up with the stone

FIG. 3.

knife and placed in a tin pail, or paint pot, and thinned down with oil to proper consistency for use. The operation of grinding with the muller may have to be repeated several times, in order to prepare a sufficient quantity of paint, but not till it is all ready is it thinned down for use; a quantity of drier may then be added, to cause the paint to harden more quickly, or varnish put in the mixed color, to cause it to dry with a glossy surface. In preparing paint for use, boiled oil is generally used to thin it down when it is intended for outside application, unless it is for decorative work, in which case a little turpentine and some pale linseed oil may be added. For indoor work, linseed oil, turpentine, and a little drier are generally used in varying quantities, according to the finish desired. The smaller the proportion of oil used, the less will be the gloss, and the greater the ultimate hardness of the coating.

94. Another blade used by the house painter is the **stopping knife,** shown in Fig. 4. This is a stiff blade with

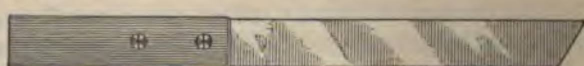


FIG. 4.

parallel edges and pointed end, used to stop or fill cracks, nail holes, etc., with putty before the painting is proceeded with. Stopping is not resorted to until after the first coat of

paint is laid, as the pores of the wood are likely to absorb the oil from the putty, and render it brittle and inadhesive.

95. The **palette,** Fig. 5, is used by the painter to prepare his colors when executing small work, such as sign

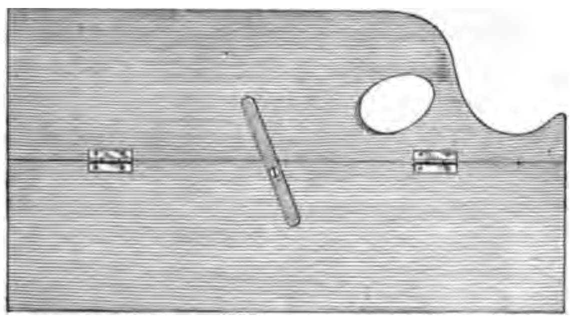


FIG. 5.

painting, interior decorations, etc. It consists of a thin piece of wood, either rectangular or elliptical in form, with a hole near one end, through which the thumb is inserted to hold it when in use. On the palette the various colors are mixed with the palette knife until the desired shade is attained, and the brushes are then dipped in the mixed color as it lies on the palette, instead of in the paint pots, as is the case with the colors mixed in large quantities for a general house painting.

96. If the colors on the palette are too thick to be applied with the brush, they may be thinned down with linseed oil, to hold which, a **palette cup** is used. This is a little tin vessel about two inches high and one inch in diameter at the top, as shown in Fig. 6. It is secured to the palette by means of a tin spring clamp on the bottom, which grasps both sides of the wood and holds the cup and oil in a handy position for the painter to dip his brush and thin down his paint.

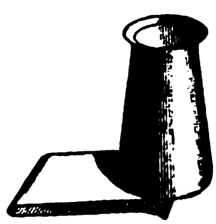


FIG. 6.

BRUSHES.

97. Brushes are of various shapes and sizes according to the different purposes for which each is used, and are made of different materials, adapted to suit the character of the work and vehicle to be spread. Hog's bristle, camel's hair, badger's hair, and sable are the most common materials used in the manufacture of paint brushes, though bear's hair and ox hair are also utilized for special work.

98. The largest brushes, such as shown in Fig. 7, are made of bristle and called **pound brushes.** They vary in

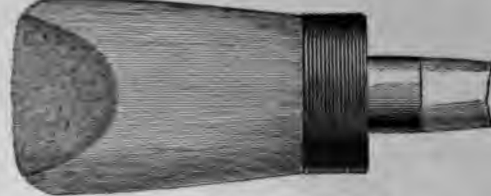


FIG. 7.

size, being distinguished under the marks, "1-0," "2-0," "3-0," etc., up to "8-0," which is the largest size, and are made in three shapes, round, flat, and elliptical, with flat or chisel-shaped edges. The round and elliptical brushes are used most frequently, as they hold a considerable quantity of paint, and will spread it over a large surface without redipping. They are also used as dusters to clean the surface to which the paint is to be applied, and such usage softens up the bristles and makes them more serviceable when subsequently used as paint brushes.

99. The bristle brushes, next smaller in size to the pound brushes, are classed under the general name of **tools,** but are, in some cases, distinguished under a qualifying term,

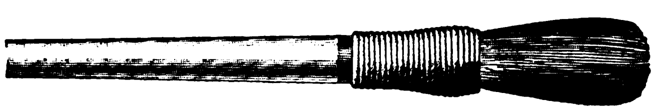


FIG. 8.

such as *sash tools*, etc., one of which is shown in Fig. 8. Tools are flat, as shown in Fig. 9; round, as in Fig. 8; elliptical, chisel edged, etc., similar to pound brushes,

FIG. 9.

and are used in connection with the latter to spread the color on the more inaccessible parts, such as the moldings around panels, sash bars, dentil courses, railings, and all

FIG. 10.

other parts where the larger brush would be too cumbersome. The smallest bristle brushes are called **fitches,** and like the tools, they are usually qualified by another name to designate their particular purpose. The ordinary fitch is

FIG. 11.

shown in Fig. 10, and is precisely similar to the sash tool shown in Fig. 8, but smaller in size. Figs. 11 and 12 show

FIG. 12.

two sizes of a brush, known as the **lining fitch,** used in connection with a straightedge to produce straight lines or stripes. In the smaller size, the bristles are held in place by a piece of tightly wound cord, while the larger one is bound in tin.

100. Varnish brushes are usually flat with a chisel edge, and made of a finer quality of hair than the ordi-

FIG. 13.

nary paint brushes. Bristle varnish brushes are used for ordinary work and may be obtained in sets of four, as

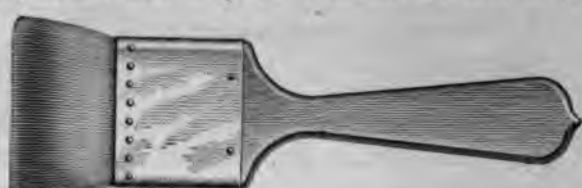


FIG. 14.

shown in Fig. 13, but for furniture and other fine work, camel's-hair, badger, or sable varnish brushes, such as shown in Fig. 14, should be used. There are many other brushes used in the house-painter's work, each used for some specific purpose to be hereafter described. All brushes should be thoroughly washed after each using and hung up by the handles, and laid over a ledge to dry, so that the bristles will not become bent or in any way out of shape. The larger paint brushes may be readily preserved in a soft condition, by boring holes through their handles

FIG. 15.

and suspending them in a tub of water on nails driven for the purpose, as shown in Fig. 15. The water should just cover the bristles and not reach the binding, as the latter is likely to swell and burst if permitted to get thoroughly soaked.

TOOLS USED IN GRAINING AND DECORATING.

FIG. 16 (a).

101. Graining is that branch of the painter's art which consists of the imitation of the natural veining curl, etc. in the grain of various woods. It is accomplished, in part, with the same brushes used for house painting in general, but requires special implements for the finishing part called overgraining.

FIG. 16 (b).

102. Graining combs are tools, usually made of metal, as shown at (*a*) and (*b*) in Fig. 16, or of leather, as shown at (*c*), with which the straight and wavy grain of certain kinds of wood is imitated. The paint, of the proper color for the grain, is laid on the surface with a pound brush, and then immediately scraped with the graining comb, which removes the applied color in streaks, and leaves a fine, thread-like grain over the ground or body color, applied and allowed to dry before the graining was commenced. Graining combs usually come in

FIG. 16 (c).

sets of eight, and vary in width and coarseness of teeth, as shown at (*a*), (*b*), and (*c*) in Fig. 16, though single combs, such as shown in Fig. 17, may also be obtained. The **vein-**

FIG. 17.

ing horn, shown in Fig. 18, is used in the same manner as the comb, but only when the graining is to be in broad veins instead of a series of fine, parallel lines. The veining horn is made of a piece of celluloid or horn, and, after being covered with a piece of cloth, is drawn along the freshly painted surface, to remove the color and expose the body color or ground.

FIG. 18.

103. Graining Brushes.—Where the veins are few and far apart, the color used in graining is applied in streaks, instead of a solid coat, and for this purpose a number of brushes called **shaders** are used. Fig. 19 shows a large shader, which is nothing more than a camel's-hair or sable brush, and is used both to apply the graining

FIG. 19.

color as described above, and to partially remove the overgraining tint where it is desired to produce the effect of veins, which are not as marked as those obtained with the veining horn.

A number of different sized camel's-hair brushes, called

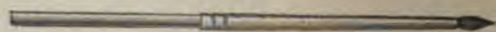


FIG. 20 (*a*).

pencils, shown in Fig 20, are used to mark the grain in certain woods. These are usually mounted or bound in the

small end of a goose quill, while in the large end a wooden handle is inserted, as shown at (*a*), Fig. 20. Pencils, as distinguished from brushes, are so called because their purpose is to draw lines or stripes instead of to spread the color over

FIG. 20 (*b*).

FIG. 20 (*c*).

a considerable surface. They are always made of soft hair, such as sable or camel's hair, and are either pointed on the end as in Fig. 20, or cut off square as in Fig. 21, which shows an implement called a **pencil overgrainer,** and consists of a number of camel's-hair pencils, mounted on a broad wooden handle, and used to mark the parallel grain of various woods.

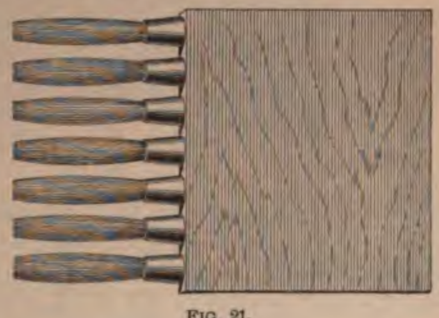


FIG. 21.

The **oak overgrainer** is shown in Fig. 22, and is used in the same manner as the pencil overgrainer, except that the hair of the brush is divided into a series of small tufts, by means of a graining comb, such as shown in Fig. 17. The comb is drawn through the hair of the brush after the latter has

FIG. 22.

been charged with the color, and the bristles so parted are drawn over the surface to be grained, thereby producing the effect of an irregular-grained surface peculiar to oak, ash,

and similar woods. The **mottler**, shown in Fig. 23, is used to produce that peculiar mottled appearance prevalent in several hard woods, and the **dabber**, Fig. 24, is required

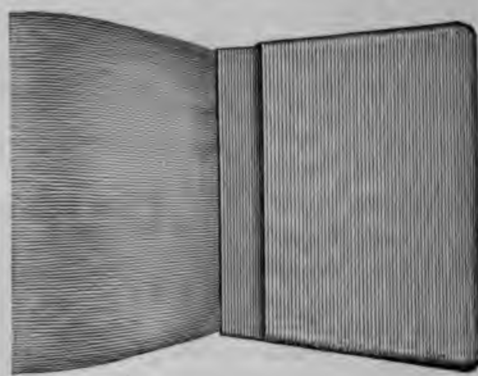


FIG. 23.

where a blending of one tint into another is desired. The dabber is cut off square on the end, as at (*a*), Fig. 24, or diagonally, as at (*b*). The mottler and dabber are usually used dry and applied to the painted surface with short quick

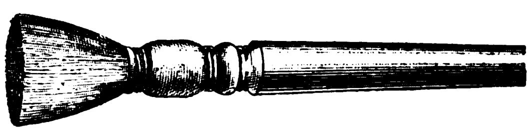


FIG. 24 (*a*).

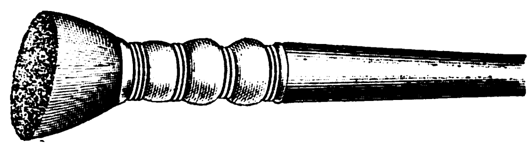


FIG. 24 (*b*).

strokes, to remove and replace little particles of color, thereby producing the soft, mottled, or graded effect of one vein running into another. The dabber is sometimes called a *blender*.

The **badger softener**, shown in Fig. 25, is used after the overgraining is complete to soften the edge of the parallel

veins and take away the appearance of a hard line or stripe, produced by the use of the pencil, overgrainer, veining horn, or comb.

The above are the principal tools used in general house painting, whether the work is exterior or interior, but the execution of fresco painting and other branches of interior decoration requires additional brushes and other implements to be considered when these subjects are discussed.

FIG. 25.

LAYING THE COLOR.

APPLICATION TO WOODWORK.

104. New Work.—It is necessary, before entering on the process of painting, to clean off all glue spots, etc. In this operation, the painter uses the stopping knife (Fig. 4), care always being taken not to score or dent the surface of the wood. The dusting brush should, in this part of the work, be freely used.

105. Knotting.—The next operation is called knotting, to guard against the appearance of knots in the finished work, by arresting their absorbent quality, or closing the apertures of the fiber and thus preventing the effusion of gum or sap. Wood should, before use, be thoroughly dry, but as this is a matter not within the painter's control, he must employ all skill and industry to counteract any neglect in the choice of properly seasoned wood. The object of painting being to preserve the more perishable parts of the structure from the deleterious effect of weather, heat, gases, etc., it is well to note that paint, applied to unseasoned wood, confines the sap and moisture, and thus surely hastens decay. **Patent knotting** is a specially prepared composition

readily purchasable. The following receipts are, however, given for the preparation of like compositions:

1. Mix together ½ pint of japanner's gold size, 1 teaspoonful of red lead, 1 pint of vegetable naphtha, and 7 ounces of orange shellac. Keep in a warm place till the shellac dissolves; this mixture must be frequently shaken.

2. Mix together, with glue size, a small quantity of white and red lead powder, and apply while warm.

The knots should, in certain extreme cases, be covered with silver leaf.

106. In all well built structures, the woodwork receives at least four coats of paint. The first process of painting is called **priming**, applied for the special purpose of diminishing the absorbent quality of wood or plaster. The paint used for this purpose is generally a mixture of white lead and red lead, with a proper proportion of driers, but when the finishing colors are to be of somber hue, the priming coat may be dark green, dark brown, etc. The painting may be done with a dull lead color, made of vegetable black and white lead in equal quantities. These colors should be mixed with boiled oil, for out-of-door, and linseed oil for indoor, work, adding, in either case, a small quantity of turpentine, the proportion being three parts of oil to one of turpentine. For rapid absorption by the new wood or plaster, the priming coat should be thin. Some painters adopt the reprehensible practice of laying a coat of charcoal size over the wood. No durable effect is thereby obtained. The size, to a great extent, arrests the absorbent powers of the wood or plaster, but prevents the proper adhesion of oil paint, which splits and peels off. Charcoal may, however, be used with advantage on old work, where the grease prevents the proper drying of oil paint, but, even in such cases, it is better, when possible, to remove old paint from the wood or plaster, until the surface is reached, on which a coat of oil color may be successfully applied.

When thoroughly dry, the priming is to be rubbed down with glass paper. This operation, although in itself simple,

requires care to make the rubbing equally effective over the entire surface. To obtain this result, glass paper should be wrapped around a flat piece of wood or cork (cork to be preferred), say 4 in. × 6 in. and 1 inch thick. This should be rubbed equally over the whole surface which will thus be smoothed without injury.

For use on the edges of panels and similar situations, glass paper may be wrapped over a piece of chisel-shaped wood, while for the curves of moldings, a piece of cloth around the end of the finger is used. All the dust caused by the glass paper having been carefully removed with the duster, the next operation is that of stopping.

107. Stopping is the filling in and making good all nail holes, bad joints, splits, etc. with putty, or with a paste made of putty and white lead, called hard stopping, which is done with the stopping knife. This is another of the operations, simple in themselves, which, in execution, demand care and attention. It is not sufficient to merely press a small quantity of stopping into the interstices and then smooth it over; for, as the stopping dries, it contracts and sinks below the surface, leaving openings quite as great an eyesore as ever. With the stopping knife slightly raised above the surface, the stopping should be forced as far into the crack as possible. In a day or two before the second coat is laid, the stopping will—owing to shrinkage—be found nearly level with the panel, and may then be smoothed with the stopping knife.

Where a panel or other part of the work receives a blow, and a dent or shallow concavity is formed, it must be clear that the mere film of stopping required to level such a spot, is almost certain to peel off, leaving a place totally uncovered by paint. To avoid such a result, the best way is to deepen the recess in parts, by pricking holes in it with a brad awl, which should incline in different directions. Deep fissures are thus formed into which the stopping is to be forced, and the portions spread over the delves will thus be, as it were, nailed to the wood by the filaments penetrating these

openings. The surface having been again smoothed off with glass paper, the second painting is proceeded with.

108. Intermediate Coats.—For the second coat, the same paint used for the priming, or white lead thinned with oil and a little turpentine and driers, may be employed, the proportion of driers, for ordinary cases, being 1¼ ounces to 10 pounds of white lead; but in winter, or in a damp climate, the proportion of driers must be increased. It should be observed that second color for new work is made up chiefly with oil, as it best stops the suction of the wood, but second color for old work is made up chiefly with turpentine, because oil would not, in this circumstance, either dry or adhere so well.

The color should be spread on as evenly as possible, and to effect this, the brush should, as soon as the whole, or a convenient quantity, is covered, be passed over it, in a direction at right angles to that in which it is finally to be laid off. This operation is called **crossing**. After crossing, it should be again laid off softly and carefully, in a direction contrary to the crossing, but in accord with the grain of the wood, taking care that none of the cross brush marks be left visible. In this case, good workmanship demands that the paint be laid evenly and the brush marks unobservable. In laying off, the brush should be started in that portion of the work already done, so that the joining be imperceptible. Every coat should be perfectly dry and all dust carefully removed before a succeeding one is applied. In the third painting, oil and turpentine should be used in equal proportions.

109. Final Coat.—The fourth painting may be considered the finishing coat, although a fifth—always with great advantage—is often given. The finishing coat must not, by any means, be applied unless that immediately preceding it, be entirely and uniformly dry, as regards surface; for, if in one part it be glossy, and in another dull, it is evident that the absorption of the wood is not stopped and the third or fourth coat, as the case may be, must be repeated, before the finishing coat is laid.

110. Old Work.—In commencing to repaint old work, the surface should, in the first place, be gone over with the stopping knife and all excrescences removed. It is then rubbed with powdered pumice stone and water, the greasy parts being also rubbed with lime.

111. Cleaning old paint may be effected by washing it with a solution of pearlash in water. If the surface is greasy, it should be treated with fresh quicklime mixed in water, washed off and reapplied until the grease is entirely removed.

112. Removing Old Paint.—Dissolve 2 ounces of soft soap and 4 ounces of potash in boiling water; add $\frac{1}{2}$ pound of quicklime; apply hot and leave from 12 to 24 hours. This will enable the old paint to be washed off with hot water, and is a neater and more rapid way than burning off, etc.

113. Parts from which the paint has been entirely removed, and decayed patches, must be gone over with a coat of priming color, and fissures, holes, etc. made good with stopping. The first coat is then to be applied, mixed with turpentine. The quality of the next coat, which will be the ground, or first-finishing, coat, depends on the manner in which the work is to be finished. A general rule for finishing in oil is that the under, or first-finishing, coat should be in oil. All turpentine grounds must have a little oil mixed with them, and all under coats, except the priming, or first coat, in new work, have a small quantity of turpentine added. There are, however, pigments of a cheaper grade, but permanent character, which in tone approach the very best, and these may, with advantage, be used as a first-finishing coat, while the final coat is laid with the finer grade of paint.

114. Flatting is the term given to that method of painting resorted to when it is desired that the dry surface present a flat or dull appearance, without any gloss. The paint used for the first-finishing coat should be, in this case, rather thicker than that employed under other circumstances.

Mixed with linseed oil and turpentine, it should be rather darker than the flatting is intended to be. Special care should be given to the laying of all the coats preceding the flatting. They must be very evenly spread and smoothed with glass paper to be perfectly even, otherwise the smallest irregularities will appear in the finished surface, to the injury of that perfectly flat appearance in which lies the real beauty of the work. The pigment used in flatting consists of white lead, with which the necessary coloring matter is mixed; turpentine alone, with a small quantity of copal varnish, being added. This causes it to bind better. If carefully done, the work will bear one washing without injury to the flatting or the appearance of the dead surfaces. The color should be rather lighter than that finally required, as it darkens a little while drying. Necessary as it is that the coat preceding the flatting should be dry, it ought not to be absolutely hard, for the flatting, mixed with turpentine, and a little varnish, should slightly dissolve the surface, so as to become, in a measure, incorporated with it. By this partial incorporation much beauty and durability are obtained. If, on the other hand, the previous coat had become quite hard, the flatting would, in most cases, appear streaky when dry, and be likely to split and peel off.

Owing to the special composition of the paint used in flatting, it dries very rapidly, and two, four, or six men, may, at one and the same time, be employed in flatting a wall. In a small room, however, two men are sufficient. A plank laid across step ladders, or trestles, is placed in front of the wall, at about half the distance from the floor to the ceiling One of the men stands on this platform, while another stands on the floor. The latter commences the work, painting a strip about 18 inches wide and carrying it up as high as he can conveniently reach, working rapidly and crossing occasionally, so that no brush marks, in any one direction, be visible, laying off very lightly so that the points of the hairs just skim over the work. The man above proceeds with the operation from the line where his fellow worker leaves it, and carries it up to the top of the wall, the first man

meanwhile getting on with another strip, both artisans being exceedingly careful that no break occurs, and that the lines at which their work joins is invisible.

Brushes, called **stipplers**, are used to flatten the tint after it is applied. These are broad and flat, and in form resemble

FIG. 26.

a hair brush (Fig. 26). In practice, the stippler is gently dabbed against the wet paint, producing a level grain over the whole surface, something like the "tooth" on the drawing paper known as "cold pressed." These brushes may be obtained in various shapes and sizes—the handles of some being continuous with the back; in others, fixed as in the illustration. The adoption of either form is, of course, a matter of taste. In flatting a door, the panels must be finished first, and great care taken to carry the paint fully into the edges and corners. Then it is convenient to paint the muntins, next, the upper, middle, and lower rails, and, lastly, the stiles. Should any brush marks appear at the parts where the work is necessarily in cross directions, they should correspond with the grain of the wood at the joints, as it in reality exists at these points.

PAINTING PLASTER.

115. To paint plaster, the first coat should be of white lead, mixed with linseed oil and a small quantity of litharge, the paint being rather thinner than that used for general

purposes, that it may fully enter into the absorbent surface of the plaster. The next coat, also, should be thin, so that the plaster may be thoroughly saturated. As this will be but partially absorbed, the third coat is made much thicker, mixing with it spirits of turpentine, and some of the coloring matter approaching the future tint of the room. The fourth coat should be thicker still, and mixed with equal parts of oil and spirits of turpentine, together with the dry ingredient, sugar of lead, instead of litharge. The color should be much darker than that which is to constitute the finishing coat. All these coats should be laid on with the greatest attention paid to smoothing, and each thoroughly dry before the succeeding coat is applied, besides being well rubbed down with glass paper. The last coat, preceding the flatting, should not, however, for reasons already given, be quite hardened.

116. New Walls.—It does not appear that any painting in oil can, with serviceable effect, be done on stucco, unless the stucco be dry, in itself, and the walls have stood sufficiently long to have given the brickwork the requisite degree of dryness. Stucco, on furred walls, when prepared with abestos, may be painted much sooner than otherwise. The art of painting stucco, so as to stand well, lies, for the most part, in attention to the following observations. The expansive power of water is such, both in freezing and in evaporation, that when it meets with any foreign body obstructing its escape, as, for instance, oil painting, it immediately assails the obstruction, forming, in so doing, a number of vesicles, or cells, containing an acrid lime water, which forces off layers of plaster, and frequently denudes large sections of wall surface, extremely difficult to cover up. Two or three years are not, in most cases, too long a period for stucco to remain unpainted. In work entered upon for mere purposes of gain, just so many weeks are, however, reluctantly allowed. The merits of some patent liquids are, indeed, so set forth as to claim, in spite of the natural properties of bodies, that stucco, washed over with these

nostrums, may be, immediately after, painted with oil colors. Instances may, in fact, be cited, and experiments adduced, which, at first glance, seemingly contradict, but shall, upon investigation, be found to confirm the laws of nature.

These precautions attended to, there is no better material for priming, or applying the first coat, on stucco than linseed or nut oil, boiled with driers, care being taken, in all cases, not to lay it on too thick, nor in larger quantity than the stucco will absorb, rendering the surface rough and irregular. It should then be covered with three or four coats of ceruse, or native carbonate of lead (prepared in the manner set forth for intermediate coats, Art. **108**), giving each coat sufficient time to dry hard. If time permit, two or three days between each layer will not be too long. If the stucco be intended for finishing in some given tint, gray, light green, apricot, etc., it will be proper to prepare the ground for the desired tint by a slight advance towards it, about the third coat of paint.

DRYING PROPERTIES OF PAINTS AND OILS.

117. Painting is done with one or two objects in view—either to change the natural color of the surface to which it is applied, or to preserve that surface from the deleterious effects of air, rain, dust, etc.

Three conditions are to be observed: First, the paint must possess sufficient fluidity to be spread with a brush, and yet be viscous enough to adhere evenly to the surface, without running, besides leaving coats of equal thickness, when the surfaces are inclined or even vertical. Second, the applied paint must become hard. Third, after hardening, it must adhere firmly to the surface to which it has been applied. It has been proved that the hardening of white lead or zinc-white paints is due to the absorption of the oxygen of the atmospheric air. Since pure oil hardens, the hardening is plainly the effect of a primary cause, independent of the drier, white lead, or zinc white.

Experiments demonstrate that white lead and oxide of

zinc manifest, in many cases, a drying property found to exist, also, in certain substances which are themselves painted—lead, for instance. The painter desirous of knowing, at least approximately, the length of time required for his work to dry, considers, therefore, all the causes of the drying process, since this process is assisted by several substances having, under certain circumstances, the property of drying paint. There is, moreover, this remarkable fact, that the resultant or sum of the drying powers of each of the substances, entering into the composition of the paint, cannot be reckoned by the sum of the drying powers of each individual substance. Thus, pure linseed oil, whose drying power is represented by 1.985, and oil, treated with manganese, by 4.719, possess, when mixed, an activity of 30.828. If there are substances increasing the drying properties of pure linseed oil, there are, again, others which seem to retard it. Linseed oil, for instance, with one coat applied upon glass, required 17 days, while the same oil, mixed with oxide of antimony, took 26 days to dry. In this case, the oxide of antimony was an antidrier. Linseed oil, mixed with oxide of antimony, and applied upon a cloth painted with white lead, was dry after 14 days. The same oil, mixed with the arsenate of protoxide of tin, and applied upon the same cloth, was not hard after 60 days. Oak wood appears to possess the antidrying property to a high degree, since, in an experiment during the month of December, three coats of oil took 159 days to dry, while in an experiment during May, a first coat of linseed oil was not dry on the surface till after 32 days. Poplar seems to be less antidrying than oak, and Norway fir less than poplar. In the experiment for May, just referred to, three coats of linseed oil, on Norway fir, took 23 days to dry.

118. If, in certain substances, there is a drying activity, and in others a contrary force, there are, no doubt, circumstances under which linseed oil is uninfluenced by the nature of the surface on which it may be spread. For instance, in the experiments alluded to, one coat of linseed oil was laid

upon the surfaces of copper, brass, iron, porcelain, and glass, and the oil was, in every case, dry after 48 hours. A substance may be drying or antidrying, under different circumstances, attributable to the temperature, the presence or the absence of some other substance, etc. Metallic lead, for instance, well known as possessing drying qualities, is antidrying in respect to linseed oil applied upon metallic leaf. Painters, desirous of thoroughly understanding the nature of their work, must consider the drying of their paint after the manner just pointed out. By so doing, and, in certain cases, fully examining results, differing one from the other, they are enabled to modify and improve ordinary methods. Linseed oil is naturally drying, and this property always increases by its admixture with white lead and, in certain cases, with oxide of zinc. If this mixture is not sufficiently drying, recourse is to be had to an addition of oil, boiled with litharge or manganese. It is, at the same time, necessary to consider the nature of the surface painted over, whether it be a first, second, or third coat; also, the temperature of the air, the light, etc.

Drying oil, boiled with litharge or manganese, loses, from our present point of view, some of its value, because it may be dispensed with in the second and third coats and even in the first, when natural drying is aided by the temperature. Pigments themselves may, moreover, act as substitutes for it, as in the case of light colors, which are altered by browns or yellows. Linseed oil, exposed to air and light, becomes drying and loses its color, and may, therefore, be employed with white lead or zinc white, without impairing the whiteness of either. The association of oxide of zinc with carbonate of zinc, making it possible to dispense with a drier, presents a ready way of avoiding the inconvenience of colored driers. This circumstance also indicates that new combinations of colorless substances may be found, presenting great advantages. Experiments fully explain the function of linseed oil, or, more generally speaking, of drying oil in painting. Indeed, when oleic acid is mixed with metallic oxide, which may solidify it, it passes instantaneously from the

liquid to the solid state, and there is no uniformity in the ensemble of the molecules of the oleate. The effect is different, when a drying oil, absorbing oxygen, passes progressively to the solid state; the slowness with which the change takes place allows of the symmetrical arrangement of the oily molecules, which would, were it not for the opaque molecules between them, appear transparent. But if these opaque molecules do not predominate, the painting is glittering—even brilliant, because of the lights being reflected by the dry oil as by a mirror.

GRAINING.

119. Graining is, as already stated, the imitation of the natural veining and curl of woods, and is, in the first instance, done by laying an opaque ground in strong oil paint of the general color of the wood to be imitated, but much lighter. This, when dry, is to be covered with a coat of transparent color of proper hue and full depth, prepared either with turpentine or water color.

The operations given in detail in the description of the methods of imitating various woods are performed with common brushes. When the last coat is dry, the process called overgraining is commenced. This is executed with a variety of tools already described, consisting of broad, flat, and thin brushes, hair pencils of various sizes, also combs and rubbers, as described in Arts. **102** and **103**.

These being, as occasion requires, dipped into turpentine or water, are passed quickly and lightly over the paint, so as to leave untouched, according to the skill and fancy of the grainer, the streaky grains, curls, and knots intended so to remain. The surface is then immediately wiped off with a rag, which takes up the upper coat of the paint, dissolved by the turpentine or water, leaving the graining as required, and exhibiting the ground between the lines. The various lines, eyes, veins, knots, etc. are then touched and retouched until the desired effect is obtained—the work being subsequently varnished. The skill and practice of the grainer are,

of course, in these operations, greatly called into requisition—operations, by some so admirably executed, as to imply, in spite of anything stated to the contrary, a degree of taste, observation, and dexterity of hand, placing this art far in rank above that of plain painting.

120. The student must, for their faithful production, give special attention to the structure, growth, and ornamental character of various woods. A useful collection of wood specimens may for this purpose be obtained by acquiring a few feet of veneers, cut from each of several woods, such as those hereinafter named, or others. Glued on common pine plank, French polished, and oil rubbed, these veneers make an excellent set of grainer's samples.

The plain painter having previously given the new wood three or sometimes four coats of paint, the grainer commences his work by laying the graining ground, differing in composition according to the wood to be reproduced.

121. **Bird's-Eye Maple.**—The ground is to be mixed of white lead and vermilion, of which latter only sufficient must be used to neutralize the blue tinge of the white lead, but not to give it a pink tint. The mixture must be rather oily, that is, it must contain a good quantity of oil, in order that the graining color may not be so much absorbed as if the surface were flatted, or coated with color mixed with turpentine. In order that the graining colors usually mixed with beer may adhere to the ground that has been painted in oil, it is necessary that the surface be prepared. This is done by passing over it with a sponge moistened with beer and rubbed with whiting; when this is dry, the distemper, or beer-mixed color, will work freely over the oil and adhere to it. This process is called **clssing.** The graining color, which is ground in beer instead of oil, consists of Vandyke brown, brown lake, drop black, or similar colors, according to the tint required, whether brown, yellow, or black maple. With a tool the color is laid over the whole panel and worked to a level with the mottler (Fig. 23). Then lights are taken out from the still wet color by dabbing the

surface with the mottler, and at the same time drawing it along, by which means the color is, in certain places, removed. Soften the whole with the brush called the softener (Fig. 25) so set as to spread outwards and be rapidly as well as lightly drawn over the work, without leaving any brush marks. Next, with a thinner mottler, work around the edges of the lights, giving a pointed tendency to their forms, likewise filling in the finer work in the darker spaces. When this has again been softened, use the dabber (Fig. 24).

122. Gnarled Oak.—The ground for this wood varies according to the exact tint required. It is usually composed of white lead and yellow ocher, or Venetian red and yellow ocher, and various tints resulting from their admixture. Orange chrome in different proportions with white lead may, however, be used; for, the tone of the whole work in graining is, in a very great degree, influenced by the color of the ground. The ground in this case, as in that of bird's-eye maple, should be rather oily, but the cissing must be done, in this instance, with whiting and water, instead of beer.

The graining color is to be made of Vandyke brown, mixed entirely with water, the work being rubbed in with a tool and mottler (Fig. 23). Next, with a tool dipped in a very dark mixture of the graining color, dab patches on the wet work where the knots are required, then, with a damp, coarse sponge, dab the dark knots well over, and with another piece of sponge, draw around the knots connecting them into groups.

In commencing the overgraining next day, pass over the whole with the same color as before, but very much thinner, and with a softener, draw the color into groups of knots; next take out some lights and nicely soften the whole in every direction, also with the badger softener (Fig. 25). In first-class work before overgraining, dip a small sable pencil (Fig. 20), in Vandyke brown and draw fine free veins from each of the groups of knots to the others, or to such spots as will permit a free play of the lines. By using water only,

in mixing the graining color, the grainer is enabled to overgrain, without previously applying a coat of varnish to bind the work, which would be necessary before he could apply a second wash, had beer been used in the first color. When dry, two coats of pale oak varnish are to be applied.

123. Satin Wood.—The ground is to be composed of white lead, just tinted with chrome yellow, raw sienna, and yellow ocher, the cissing to be done with whiting and beer. The graining colors may be made of either of the following pigments: middle chrome and drop black, Vandyke brown, raw sienna and Vandyke brown or York brown; the work to be rubbed in level with a tool and the mottler. A rather coarse sponge is then wet with beer and drawn down the work, so as to leave rather broad streaks running in a slightly wavy or oblique direction, and softened with the badger softener. Next, with a clean, moist, camel's-hair mottler, the edges of the streaks are worked down with a jerky movement, so as to give that varied and fanciful appearance so much admired in the natural wood.

The overgraining color is to be mixed in beer, and composed either of tints of Vandyke brown, and black, or other pigments of similar character, but differing from those used in the ground. The heart must be done with a small sable pencil, the work being slightly brushed up with the badger. The rest of the overgraining is to be done with a sable tube overgrainer (Fig. 21), or with a sable flat overgrainer (Fig. 22), the hairs of which have been separated with a comb.

124. Of **mahogany** there are many shades. The following are, however, the colors generally used, varied according to taste, or darkened by the addition of pigments of a deeper hue. The ground color is to be mixed of Venetian red, yellow ocher, and white lead; orange chrome may be, however, substituted for yellow ocher, the cissing being done with whiting and beer. The graining color is to be made of Vandyke brown and black, burnt sienna, with black or with Vandyke brown, to suit the ground.

The color which is to be mixed with beer is rubbed in

dark with the tool and mottler; then with a clean and moist camel's-hair mottler, it is carried out according to the method described in relation to satinwood; or, to produce a feather or curl, the color is drawn with the badger from the sides towards the middle of the panel. Much taste and skill are required in the next process, which consists in working up the feather or curl. This is done by gathering up, as it were, the grain from each side to culminate in the middle, working towards a point which must become more and more elongated. The process and effect are difficult to describe, but the workman is advised to adopt nature as his model. When once he understands the result to be obtained, and the means at his disposal, he will, with a small amount of perseverance and industry, soon discover the method of working by which he may best achieve his purpose. The curl and mottling of satinwood are so much like those of mahogany, that the same manipulative process can be adopted for both, with this exception, that the pattern in the former is smaller than that in the latter.

The overgraining color in mahogany is made of Vandyke brown, with a little crimson lake. The tools are the hog's-hair or sable overgrainer and a small overgraining comb. In a curl or feather, the overgraining must follow the direction of the curl, rising from the center and becoming gradually more pointed until it is lost in the general mottling of the wood; if the wood is to be mottled only, the overgraining must run in the direction of the mottling. Should the work, when thus far finished, be found too light in color, or not sufficiently rich, it may be varnished or megilped—the megilp being made of boiled oil and turpentine. When this is dry, a mixture of brown lake and black, or burnt sienna and black, or Vandyke brown and crimson lake, may be rubbed over it, until the required tint is obtained. The whole is to be softened, and, when dry, again varnished.

125. Walnut.—The ground for walnut is mixed of Venetian red, yellow ocher, and a small quantity of burnt umber with white lead; the work is then to be cissed in with

whiting and water. The graining color is Vandyke brown, mixed with water; to be rubbed in with a tool and mottler, then mottled in the manner described in the first process for maple, and afterwards well softened. When the color is quite dry, take a sponge dipped in beer, and wet the whole surface thoroughly. When this is dry, commence the overgraining. The color for this process is Vandyke brown and drop black, mixed with beer.

With a light tint of this mixture, just sufficient to show, and a hog's-hair overgrainer, sketch the general design of the grain and soften, when dry, with the same tools, the overgrainer being divided with a comb. With a darker shade of the same color, work up the graining to the required design, softening continually during work. After this, a good effect may be produced by dabbing the work with a damp piece of coarse sponge, then softening upwards, or in the direction taken by the grain. In superior work, varnish must be added. When dry, the whole is to be washed over with Vandyke brown, or burnt sienna and water, then mottled and well softened, and after this treatment varnished again.

126. Quartered Oak.—The ground for quartered oak is yellow ocher and white lead, or Venetian red, yellow ocher, and white lead. The graining color is a mixture of turpentine, linseed oil, patent driers, and raw or burnt umber with black, according as the oak is required to be light or dark. The work is to be well rubbed in, even and clear; then with a gutta-percha comb pass over the parts required to be veined; and with a steel comb repeat the process with a wavy motion.

Next wrap a piece of soft rag over the thumb, or over the veining horn, and wipe out the light markings, taking care that no dark edges are left where the color is wiped away—a result achieved, by moving the cloth over the thumb so as to secure a clean piece for each stroke. The overgraining is now to be commenced by damping the work well with a sponge dipped in fuller's earth, pipe clay, or whiting and

water. The color to be then used is Vandyke brown, mixed with water and applied with a broad hog's-hair overgrainer, to be drawn straight down the figured work. On the stiles, etc. of doors, a mottler may be used to darken certain parts, after which the whole is well softened and subsequently varnished.

127. Rosewood.—There is so great a variety of form and color of this most elegant wood, that it is almost impossible to find two specimens alike. This renders it all the more necessary that our counsel, to obtain various specimens of veneers, should be followed, that the general character of the curl may become thoroughly impressed on the mind. The student will, by this means, form his style upon the variety in nature, and, thus, more likely produce varied and truthful representations than if trusting to his own fancy to design the wood.

The ground is prepared with vermilion lake, and flake white, mixed in a rosy tint, partaking more of the pink than scarlet. When the ground is quite dry and smooth, take Vandyke brown, nearly opaque, and with a small tool spread the color in various directions over the ground. Then, with another dry tool, beat the color, while wet, against the grain —that is, in the opposite direction to that in which it was laid on. Before the color is dry, take a piece of wash leather, spread over the veining horn, and with great freedom take out the lighter veins; have ready the darkest tint of Vandyke brown, and with a sable pencil, give free and strong touches under the parts, taken out with the leather, and in other parts where required; blend off the whole with a badger softener, and varnish when dry. Another method which will produce a finish of a more brilliant character is the following: The ground is composed of vermilion, lake, and white, which must be allowed to become uniformly dry before the work is proceeded with. The graining color is formed of Vandyke brown and rose pink, ground very finely in beer; this is laid on with a common tool, but not too thickly; then, taking a common quill, draw the feather in

various directions over the wet color, giving the hand a tremulous motion in parts where it is desired to give a wavy appearance to the grain. Then take out the small, bright lights with the wash leather, or cloth, and afterwards blend the whole with the softener. When this is dry, which requires but a few minutes, give very dark touches under the light parts with Vandyke brown and rose pink, nearly opaque—the whole to be well varnished when dry.

In a third method of graining for rosewood, the ground is chrome yellow, vermilion, and white lead. The graining color is composed of ivory black with burnt sienna ground very fine, the whole being well softened after laying on. When dry, overgrain in a curly figure with a small graining brush and ivory black; shade up the knots with a camel's-hair brush, and finally glaze.

128. Yew Tree.—The ground color, in this case, is raw umber, mixed with white lead; the graining color, Vandyke brown and burnt sienna, in equal parts, all ground in beer, with a small quantity of raw sienna added. The knots and other markings are to be worked in with the graining color, when that, previously laid on, has become thoroughly dry. Another ground color is a mixture of white, yellow ocher, and Venetian red, while the graining color is Vandyke brown and burnt sienna in beer, with a small quantity of raw sienna.

129. With a view to aiding the grainer and marbler, graining and marbling rollers have been introduced. They consist of cylinders, fixed in frames, by means of which the pattern engraved on the rollers is repeated. They are, no doubt, efficient in certain classes of work, but their use does not come within the scope of this section.

MARBLING.

130. Having, in the section on graining, recommended that the student procure, for special study, a collection of wood veneers, we have a like recommendation to make in respect to marble. The careful student must, indeed, to

achieve success, make a study of the grain and markings from natural specimens of, at least, the principal kinds of marble in use.

131. Sienna Marble.—The ground of sienna marble is white lead; the work is then to be evenly gone over with white paint, mixed with equal quantities of turpentine and oil. After this, mix two light tints, the one consisting of yellow ocher and white lead, and the other of vermilion and white lead, both mixed with equal quantities of oil and turpentine. With separate tools, dab patches on the white paint while yet wet, and with a brush soften the patches together, great care being taken not to allow the red tint to be too dominant.

On a palette, at the side of which is placed a palette cup containing turpentine, place a small quantity of blue black, and a like quantity of purple lake; then, with a sable pencil dipped in turpentine, lay a thin wash of the blue black, then vein on the wet work, and soften; work up the veins further with more blue black, so that the color may be a little darker, but still thin; after this, with a flat camel's-hair fitch dipped in turpentine mixed with a small quantity of purple lake and blue black, apply very thin washes in some of the open spaces, and soften lightly. When dry, put in whites, with white lead mixed with turpentine, using a sable pencil, subsequently softening the work with a badger. When the paints are quite hard, apply a light varnish.

132. Italian Pink Marble.—Over a white ground, apply, as in the last case, a coat of white paint, then prepare tints of ultramarine and white lead, and of vermilion and white lead, each mixed with equal quantities of oil and turpentine, and with these, dab patches, as already described, and soften. On the palette, place some Indian red, and with a small pigeon feather dipped in turpentine, and some of the Indian red, work the pattern, care being taken again to soften well. When this is dry, mix some white lead, already thinly diluted with turpentine, and flat the whole of the work. Then, with a feather dipped in turpentine,

scumble over the work and subsequently put in whites with white lead and turpentine. When the work is perfectly hard, it is to be varnished.

133. Verd Antique.—The ground of verd antique is either black or dark green, the marbling colors being dark brown and green; with these, scumble over the work; then, with Brunswick green and white lead, scumble over again, and soften with a badger. Next, with a fitch, paint masses of white of various shapes, squares, irregular triangles, etc., and similar masses of black.

134. Serpentine marble is so called because of its supposed resemblance to the skin of the serpent. In its rich variety of color and almost indestructible hardness, it is eminently suitable for architectural ornaments. Precious or noble serpentine has nearly the same appearance as the green marbles of the East, called Egyptian green. The green is generally the cold color of the leek, but varies in shades, some appearing in the darkest olive. The veins which appear black sometimes run in a horizontal direction and then suddenly break and appear nearly upright; in other cases they seem to have undergone a violent concussion, breaking and shivering to small pieces. It is within the province of the geologist to explain this phenomenal manifestation in one of the most solid of minerals; sufficient is it, for the painter, to note the lines, so as to reproduce these as far as his skill permits. The common serpentine is found in great abundance in the Isle of Anglesea. It is not so bright or so varied as the "precious," the dark shades of green being much broader, and the light veins not so fine and reticulated. The white fossil remains, consequently, show more distinctly in small, long, square sections, of various sizes and forms. The black vein is so mixed with the darkest shades of green as to be, in some instances, scarcely perceptible, rendering the marble somewhat dull and unfit for ornamental painting.

The mode of reproducing all the green marbles, both in oil and distemper, must be the same as that directed for

verd antique. The ground must, in all cases, be black, and the different shades of green formed by scumbling the white over the black, more or less thickly, according to the variety of shade required, and, when the whole is finished, glazing with green according to the tint of the marble. The difference between scumbling and glazing lies in the fact that, in glazing, the colors are so thinly mixed as to be transparent, while, in scumbling, the color is mixed thick, and then thinly spread or rubbed on with a hard brush.

135. White Veined Marble.—The ground for this marble is white, laid very smooth; the first vein will, on inspection, be found very faint; it is the broad-vein mica, seen through a great depth of the semitransparent body of the white. The shadows of white always partaking of a yellow hue, the faint vein will appear of a reddish gray, formed by mixing white, black, and Indian red to a proper tint. This must be scumbled or spread very thinly in the forms intended for the veins to take. In relation to the formation of marbles, it must be here observed, that in ore beds of rock, veined by metallic or other substances crossing them, the veins always run in the direction of the strata, precisely as thin streams of water, if poured upon an inclined plane, such as the cover of a table slightly raised on one side. If this experiment is tried, it will be found that the seams, if commencing regularly, will, from some irregularities of the surface, soon alter their course and turn in various directions, sometimes joining together, forming a sort of star, then spreading into finer threads. Others, again, join and form a thick vein, but still running in varying lines towards the bottom. This is precisely the way in which various substances spread themselves on limestone, penetrating, of course, the surface and interspersing with the strata. From this experiment, the painter will see that, however he may vary the direction of the veins, they must all appear traveling to the same point, by different roads. Nothing can be more contrary to nature than those violent and eccentric breaks into which painters of veined marbles

are often led. This applies to all marbles, except porphyry, black and gold, and Florentine.

The first broad vein of the marble having been rather faintly painted, the veins near the surface are next put in. They are made a little darker by the addition of black, and drawn very thin, taking the direction of the broad, faint vein, and divided as studies from nature dictate. The veins nearest the surface must, of course, be darker than the others; the color darkened and warmed by the still further addition of black, with a little lake and blue. This vein should be drawn very thin, with a fine sable pencil, and made to take almost the direction of the last veining. Though very little veining is required, this little must be put in with spirit and skill, thereby enhancing greatly the beauty of the work. The whole of these veins are put on, one upon the other, while wet, then blended with the badger softener; when quite dry, the dark vein may be retouched, wholly or in part.

136. Florentine Marble.—The ground for this marble is white, with Indian red and black mixed together to form a very light reddish neutral tint. The veins are umber or burnt sienna, laid on irregularly while the ground is wet; sometimes they are very close together, and then seem to break suddenly and irregularly—an effect which must be studied from natural specimens in order to be successfully imitated by hand.

137. Black and Gold Marble.—The ground being black, paint the large spots, from which the fibrous veins are to run, with yellow ocher and white, whose brightness must be heightened by the addition of a little vermilion. The masses must be dabbed with freedom upon the ground, with a brush full of color, and, while quite wet, threads drawn from them in all directions, some, of course, larger and thicker than others. White veins, with small threads attached, crossing each other and the yellow veins in all directions, are sometimes seen running in the deepest parts of the black. Care must be taken that the threads are connected with, and run in the same direction as, the thicker

veins. If the ground is properly prepared, the yellow and white veins may both be painted at once in oil color. In cabinetwork, most beautiful imitations of the finest specimens of this marble are produced by spreading a leaf or two of gold in any part of the work where gold and silver leaf, and where white veins, are intended to run. The black ground is then to be rather thickly painted over the whole surface, covering the gold and silver leaf. After the color has been on a short time, take a round, pointed bodkin, or similar instrument, and draw this color in small, reticulated veins, from off the gold and silver leaf. The metal then shows in fine lines. The larger masses are to be wiped off with the wash leather over the point of the thumb or a piece of wood. When the black is dry, the yellow and white veins are to be painted as before directed, and drawn over the gold and silver, which by this means will, with great brilliancy, show through them. Otherwise, paint the ground in deep ivory black; put on the veins in white, yellow ocher, burnt and raw sienna, using a camel's-hair brush; glaze the spaces between the veins with a thin coat of gray, or white, over which pass a few white veins. The veins may also be put in with gold leaf.

138. Porphyry.—Mix the ground color of Venetian red with a little vermilion and white until the required tint is obtained. The first layer of spots is produced by sprinkling in the following manner: Mix some of the ground color with a larger quantity of white, in a paint pot, and use a large brush well worked in the color; hold the palette knife over the paint pot, and brush the hairs of the brush against the edge, so that as much as possible of the color may be forced out of it; then, taking the handle of the brush between the palms of the hands, roll it to and fro with a rapid motion, the ends of the hairs being below the level of the top of the paint pot, but not touching the paint. This is called wringing out the brush, whereby a further quantity of the paint may be discharged; now hold a stick in front of the work and strike the handle of the brush against it; the color that

may still remain will thus fall on the surface in a variety of small dots. Great care on the part of the painter is at this stage demanded, so as to distribute the spots equally; otherwise, while one part of the work may be left only partially spotted, others are so thickly covered that the drops will run together and form blotches. When this work is sufficiently dry, the sprinklings may be repeated by dipping the brush into a color rather deeper than the ground. It may be Indian red, with sufficient white to give it a body. The sprinkling with this color must be done very sparingly, and rather more freely in some parts than others.

The last sprinkling is to be done with a clean, small tool, dipped in white paint only; the spots to be very fine. As much color, therefore, as possible should be previously removed from the brush; when it is found that so little color remains in the brush that although it will scarcely mark a board when rubbed on it, there will still be enough to produce the fine dots. In imitating some specimens, the three layers of spots are put on, and, in addition, a narrow opaque white vein is run among the spots, from which transparent threads are in turn drawn in various directions. These cannot be added until the whole of the sprinkling is quite dry and hard, and must then be formed with a sable pencil, hard threads being drawn out with a feather.

139. Jasper.—The ground is composed of Venetian red, red lead, and a small quantity of chrome yellow, mixed with oil and turpentine in equal parts; but additional brilliancy may be given the color by vermilion or lake, instead of Venetian red. While the ground is wet, dab on spots of white, using either a piece of sponge or a tool, and soften with a badger, subsequently repeating the white touches in parts, giving them increased brilliancy. Spots of blue, brown, yellow, etc. may, in the same manner, be added. When nearly dry, veins and threads may be put in with a camel's-hair pencil.

140. Granite is a well known igneous rock, composed principally of three minerals—feldspar, quartz, and mica—

united in a confused crystallization, without any regular arrangement of the crystals. The name of the stone is derived from its granular formation. There are many kinds of granite used in the arts. Among these are the gray, red, green, violet, rose colored, etc. Those best known for architectural purposes are the gray Aberdeen granite and the reddish-colored Peterhead granite.

For gray granite, the ground is a gray made by mixing black and white; over this, spots are splashed with black and white, used separately, the work being carried out as set forth under the heading of porphyry. For the various shades of red granite, the ground is composed of Venetian red and white, the spots being black, white, and vermilion. In the same way, any of the other kinds may be reproduced.

STENCILING.

141. The study of decoration demands something more than an elementary knowledge of the art; it calls for attention to the masterpieces left by the artists of past ages. The decorator of today must be, indeed, original, but his originality will be broadened and developed by study of the successes achieved by those who have preceded him.

Nothing is, to the practical decorator, more important than a keen appreciation of the value of color—good work being frequently marred by an injudicious arrangement of tints. Much time is often lost in attempts to match the color of the wall paper with the painting of the woodwork. The true artist, instead of matching the paper, ascertains the most appropriate contrasting colors; for, the harmony of contrasts is the key of successful decoration.

142. A useful table of direct color contrasts is the following:

Blue contrasts with orange;
Blue green contrasts with red orange;
Green contrasts with red;
Yellow green contrasts with red purple;
Yellow contrasts with purple;
Yellow orange contrasts with blue purple.

In the decoration of a cornice or frieze, the general tone of whose color having been decided on, the contrasting colors for the various members may be, by this table, readily found, and the massing or blurring of the parts easily avoided. The style of contrast depends, of course, upon the design and purpose of the room. An inside room, for instance, to which sunlight rarely finds its way, requires different treatment from a bright, airy room on the sunny side of the house. The ground color of any wall paper being noted, reference to the list will at once give the color demanded by the figures on the paper or the woodwork. Thus, a blue-green ground requires a reddish-orange tint, the effect being to define the boundary of wall and cornice with elegance and distinctness. Care should be taken in tinting a cornice that the colors, as they approach the ceiling, recede from the eye, an effect attained by reducing the strength of the colors employed until that, which on the lower members is a distinct color, becomes at the top a mere tint, preserving only the original tone. Attention to this point prevents the ceiling from appearing to be too low. Decoration of any kind tends to give this effect of lowness to the ceiling; when, therefore, the light tints are kept in accord with the general color of the room itself, the more pleasing, because less obtrusive, the effect.

The stencil plate may, with advantage, be employed for the embellishment of coves of cornices, the frieze of a wall, or the panel of a ceiling. Stenciling has, in recent years, grown in favor with the decorator, the result being that a number of highly effective polychromatic combinations, never seen in the earlier days or works, have been made by the use of various sets of stencils to form one harmonious design, produced with the greatest facility and precision.

STENCIL PLATES.

143. A stencil plate is a perforated pattern, usually consisting of a sheet of paper or very thin metal, through which the design is cut as shown in Fig. 27, where *a* is

the plate in which the pattern *b* is perforated. Small connecting pieces *c*, called ties, are left in when the pattern is cut out, to secure the various parts in their respective positions. The plate is laid over the surface to be decorated, and a short, stiff brush, as shown in Fig. 28, charged with color, is used to draw the pattern on the wall, through the openings *b*.

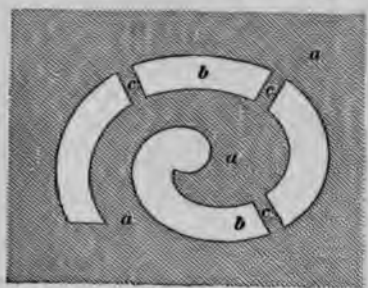


FIG. 27.

Small unpainted spaces are thereby left at the ties, which must be filled in by hand after the stencil is removed, unless the style of pattern is varied to make these ties form part of the design. Fig. 29 shows the same scroll, with the different sections flared out to a foliated form where the ties exist. The ties *a* are, in this case, an advantage to the pattern, helping outline the central leaf *b* of the foliated design.

FIG. 28.

Fig. 30 is an elaboration of the stenciled pattern in

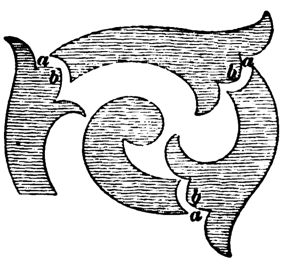


FIG. 29.

FIG. 30.

Fig. 29, in which the spaces *a*, left by the ties, are painted in a contrasted color, carried around the entire figure, as shown at *b*. From this simple example it may be seen that the introduction of a more ornamental scroll is really less

likely to take extra time than a perfectly plain one. The value of this arrangement is, of course, more apparent in the application of rapid decoration to ceilings and work further removed from the eye than the walls or dado of the room, especially when time is given to retouching the work and removing some of the raggedness inseparable from the use of the stencil plate.

144. The panels of doors also admit of such decorative effect as the judicious use of the lining fitch and straightedge for borders and moldings may produce, with a stenciled design in the corners.

Fig. 31 shows a stencil which may be used as a corner

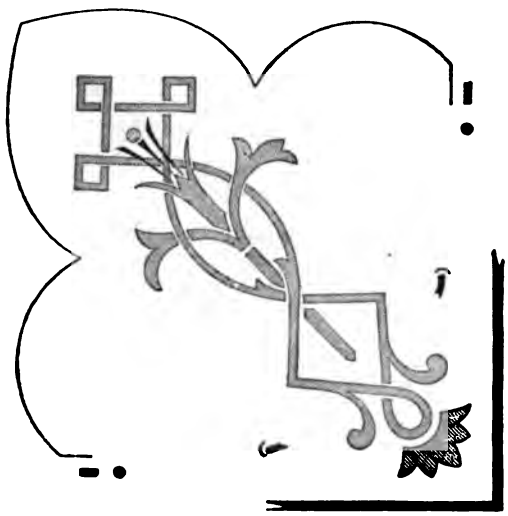


FIG. 31.

design by itself in one color, or combined with a contrasting color, laid through another stencil, as shown in Fig. 32.

Here the lighter portion is still stenciled on the surface with the stencil plate, used in Fig. 31, while the darker color is laid over it, after the former has dried.

145. Borders and Centers.—Fig. 33 shows a conventionalized maple-leaf pattern, which may be used as a stenciled border design, while Fig. 34 shows a still more

conventional pattern of foliage, which is a repetition of the same lines between *a* and *b*.

FIG. 32.

Where a stencil pattern is repeated at regular intervals as in Fig. 34, it is always desirable to have some mark cut through the stencil plate, by means of which the plate may

FIG. 33.

be set and adjusted when moved to its next position; otherwise, there is the likelihood of unequal spacing of details and the irregular arrangement of parts. This is especially the case where the ties form a part of the design and the irregular spacing would cause them to be of varying widths.

FIG. 34.

In Fig. 35 is shown a more complicated design for a border stencil where some of the ties are left to outline certain

FIG. 35.

details of the pattern, while the others are all touched out to form a continuous figure.

Fig. 36 shows a design for a stenciled cresting, which

FIG. 36.

may be used to advantage in some borders. It is composed of various foliated forms, more or less conventionalized, to suit the pattern and purpose.

Fig. 37 shows a design for a corner piece where this conventionalized foliage is carried to excess, as was typical of the later Renaissance period, but is a style of ornament lending itself most readily to the work of the stenciler.

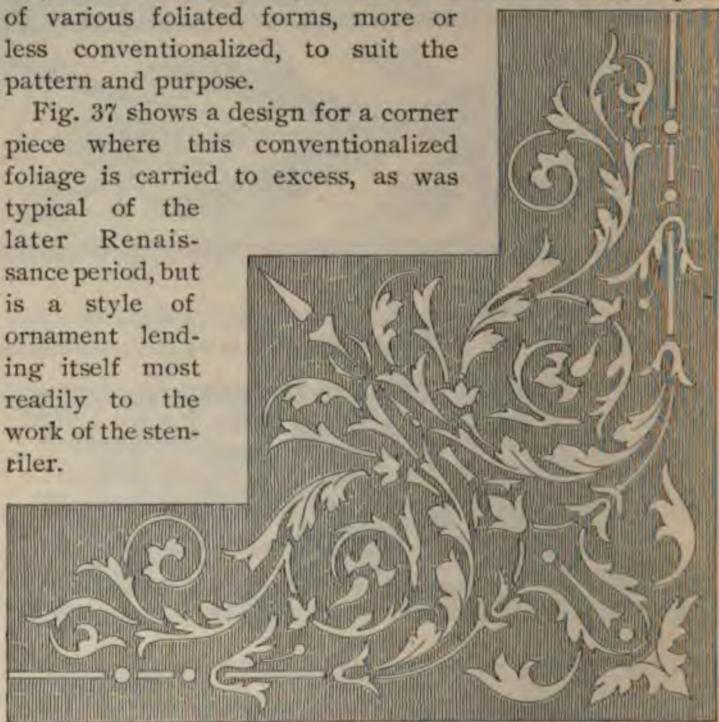


FIG. 37.

Figs. 38 and 39 show two patterns for centerpieces, which may be used on a ceiling or the face of a pilaster. Fig. 38 is executed in one color, with but one stencil plate, while Fig. 39 is prepared by first stenciling the lighter tint, and then applying the heavier shade on top of it, with another stencil, as described in connection with Fig. 32.

The flexibility of the stencil plate renders its application to curved just as easy as to flat surfaces, unless the curve exists in more than one direction. Fig. 40 shows a section of plaster cornice, the cove of which is appropriately decorated with a repeated stencil pattern, as shown at *a*, while the lower bead molding *b* is stenciled at regular intervals with geometrical figures.

Fig. 41 shows another pattern, frequently used in the coves of cornices, and is somewhat more appropriate for

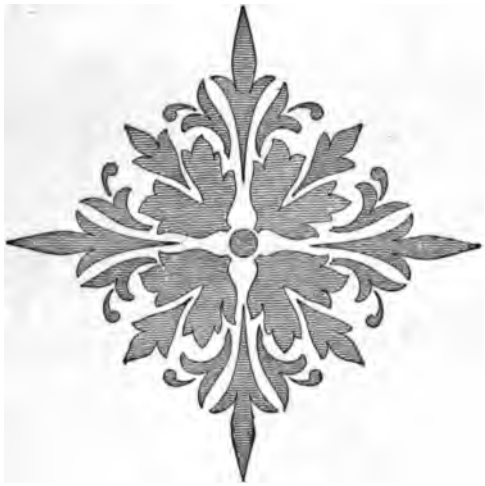


FIG. 38.

deep coves than is the ornament shown in Fig. 40, being bolder in design and better suited to a dimly lighted position.

146. Panels, Walls, Etc.—In Fig. 42 is shown a stencil design, executed with two patterns, one to draw the leaf-work, and the other to form the stems and tendrils in the darker shade. This ornament is appropriate for the end of a panel, the border lines of which are shown in the cut.

Fig. 43 shows a scheme for the stencil decoration of a pilaster, the ground of the pilaster being painted a dark color, and the stencil work overlaid in a lighter contrasting shade. Three sets of stencils are necessary for this design, one to draw the details of the dado panel, as shown at *a*; another to form each of the running borders, as seen at *b* and *d*, which may be made in one stencil, if the pilaster be not too wide, or repeated in sections if more convenient. The other two stencils are required at *c* and *e*, and may each be made in one piece, or divided through the center and applied to each side of the center line.

When stencil work is applied to ceiling decoration, the stencil plates sometimes require to be unusually large or divided into a number of sections. Fig. 44 shows the corner of a ceiling design which may be stenciled in one color on a dark ground, or in two contrasting colors, as shown.

FIG. 39.

Fig. 45 illustrates the treatment of the side walls and frieze, and the door panels of a simple room, where the stencil and brush are the only tools used, except the straightedge, where ruled lines are required. The frieze design may be executed in a monotint or stenciled, in two or more colors, appropriate to the conventional forms depicted.

For the dining room or library, a unique effect may be produced by the introduction of imitation inlaid work, on the ordinary graining of the door and dado. The method is simple and capable of infinite variations. Figs. 31 and 32 show the corner of a panel so treated, and will, if worked out on the principles laid down, be found a satisfactory addition to the usual decorative work. The door may be grained, preferably in imitation of satinwood

for the panels, and with oak stiles, or the whole may be rendered in plain oak, after which the first necessary step is to prepare a stencil.

FIG. 40.

147. Cutting Stencils.—The parts of the design possessing a scroll formation should be carefully cut with a sharp knife, as shown in Fig. 46, upon a piece of sheet iron or plate glass.

FIG. 41.

Any of the knives shown in Fig. 46 may be used for the work, but the form of blade shown at (*a*) is the one most frequently employed, particularly for straight-line work. The blade shown at (*b*) is somewhat stronger at the point, and may be used for either straight or curved work, though when the curves are very small, the blade shown at (*c*) should be used. This last is also desirable where very acute angles are to be cut out, as it admits of being worked

FIG. 42.

very closely to the desired lines. The stencil plates are cut out of a sheet of cartridge paper prepared by the application of one coat of patent knotting on each side, after the design of the stencil has been drawn.

FIG. 43.

148. Stenciled Inlay.—Having prepared the stencil, thoroughly clean the panel by wiping it with wash leather to remove any grease, etc. from contact with the distemper now to be used. The panels should have been previously varnished. If the inlay is to imitate walnut, take equal parts of Vandyke brown, burnt sienna, and a sufficient quantity of lake to impart warmth of color. These must be ground in water, and used with sufficient stale beer to render the color workable. Coat the panel entirely, and with a hog's-hair mottler vary the tints by taking out some portion before it dries, softening the whole with a badger-hair brush. When thoroughly dry, the panel is ready for the stencil.

The center of the panel and the margin may be marked out in chalk, lines being struck in the ordinary manner by

holding a piece of twine or strong cotton, on which chalk has been previously rubbed, from the marked points, then snapping the line by pulling it from the surface of the panel, it will leave its impress on the work.

This method is better than lining with the straightedge.

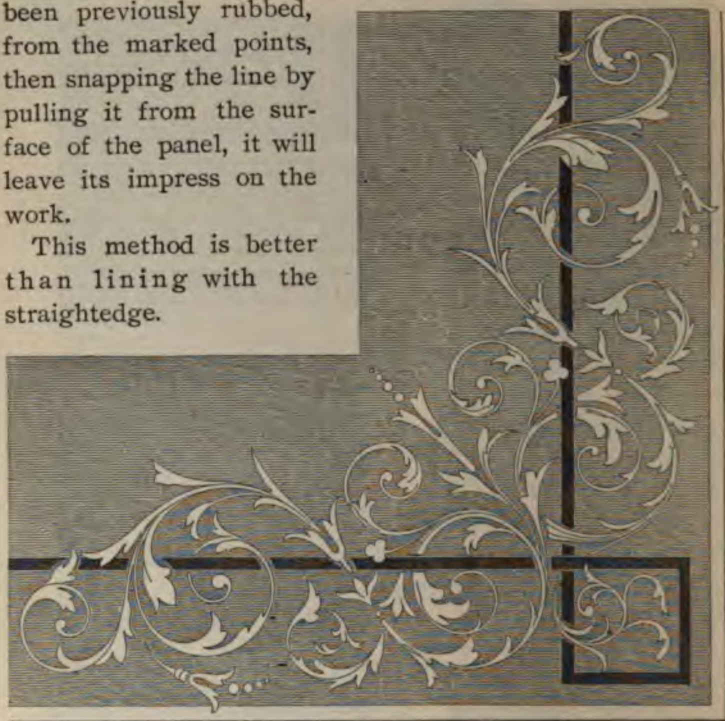


FIG. 44.

The pattern should next be stenciled on with Japan gold size, slightly reduced with turpentine, taking care to use it as sparingly as possible to prevent spreading or the formation of a ragged edge on the design. Having, in this manner, stenciled the top, bottom, and center scrolls, they should be connected by drawing the lines in the same medium, using for the purpose an angle fitch and the straightedge. In about an hour the panel will be ready to bear washing off, which should be done with a soft sponge, carefully removing the whole of the distemper and drying the panel with a chamois leather, leaving the pattern as defined by the gold size.

This is usually sufficient for all ordinary purposes, but an additional effect is imparted by penciling around the scroll

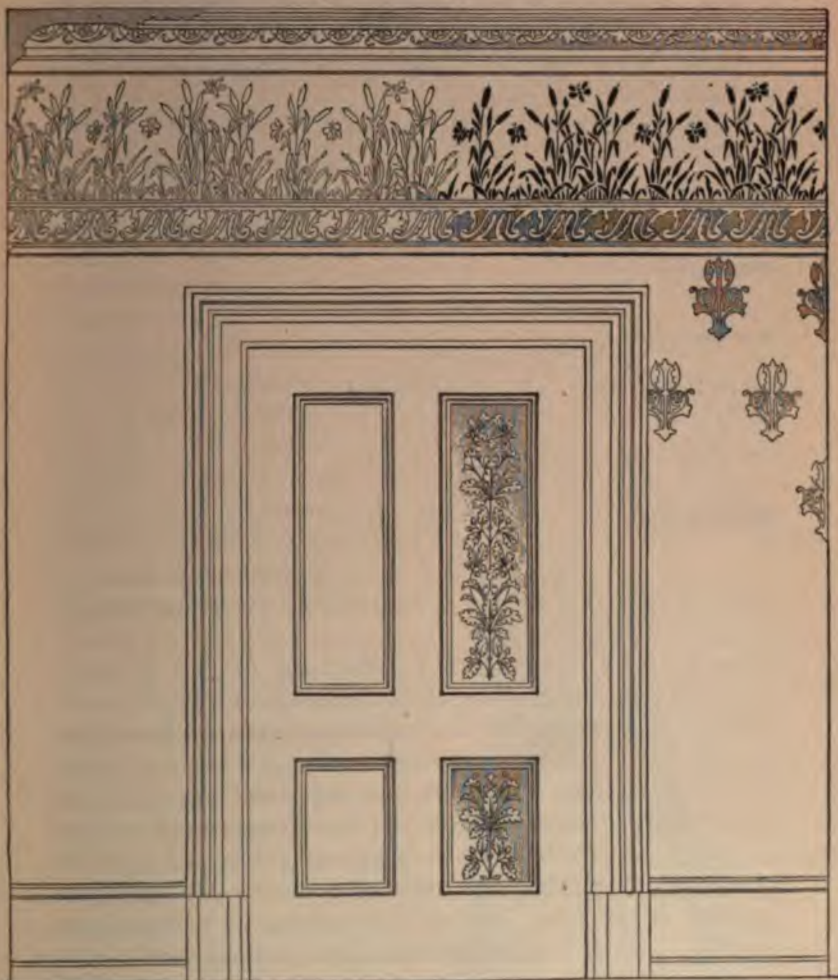


FIG. 45.

with a cream color tint, as shown in Fig. 30. This latter, it will be noticed, effectually removes the necessity of taking out ties, uniting the parts as in a real inlay. Tulip wood

may be represented between this line and the molding, by using damp lake (with beer as heretofore) and carefully cutting into the line with Japan gold size, washing off the surplus color when the size is quite hard. The moldings, architraves, etc. may be darkened with the walnut color to correspond with the panels.

Where more than one kind of wood is to be imitated, it is necessary to omit the gold size on those parts where the different imitations are required. After washing off the size, coat the parts with water color of the proper tint and proceed as before, repeating the process with every fresh color. In this way, tulip, walnut, mahogany, pollard oak, cedar, rose, cherry, or, in fact, the required imitation of any wood, may be introduced at the designer's discretion.

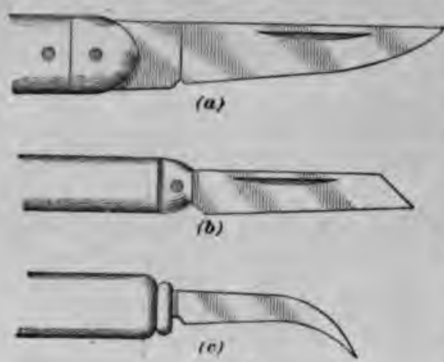


FIG. 46.

The greatest care must be taken in the process of imitating inlaid decoration, that the varnish be thoroughly hardened on the grained surface before any attempt is made to coat the work with the distemper colors. The least tackiness in the varnish will arrest the progress of the operation, as the dark pigments used for the representation of walnut, etc. would inevitably make an ugly stain, removable only by the exercise of a large amount of care and patience. An interval of at least two or three days in dry summer weather, and of a week in the humid atmospheric conditions peculiar to winter, should be allowed between the varnishing of the grained panels and the addition of the decorations. If time permits a second coat of varnish, let the work by all means receive it, before beginning the inlaying operations.

MEDIA.

149. Interior decoration may be executed in oil color, water color, or tempera, commonly termed distemper, the last named being a form of water color not ground, but simply stirred in water, and unlike the ordinary color ground in water, opaque instead of transparent. The character of the work to be executed very largely determines which of the above named media should be used, though excellent results are, from any of them, to be obtained.

150. Oil color possesses the greatest body, or consistency, and, so far as affected by the weather, is the most permanent. It is applied with brushes similar to those already described, but additional forms are desirable for particular uses. Decoration in oil color consists in the execution of a design upon walls or woodwork previously painted in body color, in the ordinary house-painter's work, which body color forms the background for the decorative design. When large surfaces are to be covered with detail, or where the work is to be carried on, day after day, from the place where it left off the previous day, oil color is preferable, as the exact shades required can be mixed with the palette knife on the palette, and when dry on the wall will not change color.

FIG. 47.

In many places it is found necessary not to execute the work directly on the wall itself, but upon canvas, afterwards stretched over the walls and secured in place. This is especially the case in what is known as tapestry painting, where descriptive

pictures are executed upon various fabrics, afterwards hung or stretched over the panels formed in the side walls of the room by pilasters or moldings. For painting canvases, an **easel** is necessary to hold the frame with stretched canvas on which the work is executed. The easel, as shown in Fig. 47, consists of a ladder-like frame, with adjustable pegs on which the canvas frame rests at such a height as best suits the painter's convenience.

As oil paint dries with comparative slowness, the resting of the hand upon any part of the painted canvas during the

FIG. 48.

progress of the work would leave a mark; the decorator in oil, therefore, provides himself with a **mahlstick**, such as shown in Fig. 48, with which he forms a bridge across the

FIG. 49.

front of his easel on which to rest his hand. The mahlstick consists of a slender rod of wood, with a felt or chamois covered ball on one end, resting against the upper part of the easel or canvas, while the left hand holds the lower end

of the mahlstick. The painter's right hand is then rested on the mahlstick while it plies the brush upon some particular part of the work. When the work is executed directly upon the wall surface, the mahlstick is still used, but the easel, of course, dispensed with. In order, however, to reach his work on the upper part of the side walls, or upon the ceiling, the painter must have a pair of trestles with which to form a platform, as shown in Fig. 49. The rungs, or steps, on these trestles admit of the building of a temporary platform at varying heights, to reach the work, in the same manner as the changing of the pegs in the easel permits the painter to raise or lower his canvas, so as to have the part he is working on directly in front of the eye.

151. Water-color painting may be executed upon the plastered wall surface—either smooth or sand finish—upon which no previous preparation is necessary, except a coat of thin size applied and permitted to dry so as to prevent the color from sinking too deeply. As water color is very transparent, it is necessary that the surface to which it is applied should be perfectly white, as the faintest suggestion of color will show through the paint and contaminate the applied tint. Besides this, there is no such pigment as white in water colors, and where the design calls for a white surface, it is desirable to leave the natural wall finish show. White pigments ground in water may be used in some places, but they belong more to distemper painting, hereafter explained, than to what is known as water-color work.

Water colors are not, like oil colors, mixed on the palette, but ground or mixed for use in saucers or cups, the proper tints being obtained by mixing one color with another, by means of a brush. The requisite depth of color is secured by grinding more or less of the pigments with a given quantity of water, or by going over the painted surface a second time to deepen the shade. The former method is, in most instances, preferable, though certain cases exist where a second painting is almost absolutely necessary. Water-color painting requires extreme care, as any error of color or

drawing cannot be corrected after the color is laid—the previous work necessarily showing through. This is the strongest distinction between the methods of water-color and oil-color work, for, in oil color, the work may be changed as many times as the painter sees fit, either by working over the first coat when dry, or by wiping it off while wet. Oil color being opaque, does not, unless very thinly applied, show what may be under it. Water-color decoration is materially affected by dampness and by strong light, and should, therefore, be used only in such places as are dry and comparatively shaded. It admits of a delicacy of treatment, however, in no way attainable in either oil or distemper, and for certain styles of design is almost indispensable.

The brushes used in water-color painting are all of the softer grades, such as sable or camel's hair, as the color is very thin and spread over the surface very evenly, so as to leave no excess on any part, to deepen the shade of that part. The soft hair brushes readily absorb any superfluous color, while the hard bristle brushes do not. In applying a water-color tint, the brush is charged with all the color it will hold, and then passed rapidly over the surface, spreading the color as far as desired, then wiped dry on a rag or piece of blotting paper, and reapplied to the painted surface to remove any excess of color. Water color is always applied in **washes** or even tints, over which the design is executed in additional washes or more thickly ground color.

152. Tempera, or **distemper,** painting is similar to water color, inasmuch as the pigment is mixed with water as a vehicle, but is in other respects totally different. The color is not dissolved in the vehicle, and its suspension is so uncertain that a slight addition of size or glue is necessary to hold it in place upon the painted surface, after the water has evaporated. The colors are all mixed to the shade required, and no amount of dilution will render them softer or more delicate, as is the case with water color. Dilution, however, depletes the effective proportion of size, rendering the color unstable and likely to drop from the surface in

powder when the distemper is dry. In distemper painting, white is applied in the same manner as in oil painting, instead of leaving the wall surface to show through, as in water color. White is also mixed with the other pigments used, in order to lower their intensity and give the color body. Painting in tempera may be, in consequence, applied over other work in the same material, unless the first work is of such a dark color that it would be likely to show through. When tempera painting is used to cover an expanded surface with an even tint, it is usually termed calcimine, and as such, largely used on ceilings and some side walls. The same material, however, is often used to execute detailed designs in various colors, and, though not as brilliant as either water color or oil, has its place in certain schools of design.

Tempera painting is executed with brushes similar to those used for oil colors, with the addition of a few others of softer hair, similar to the water-color brushes. When used to do calcimining, a broad, flat brush is required to spread the color rapidly over a considerable surface, as the color dries quickly and is likely to show marks where the dried surface is overlapped by wet paint. It is, for this reason, desirable to mix up a considerable quantity of distemper at one time, as it is almost impossible to secure the exact shade required to finish a surface started on with an insufficient quantity of color ready mixed. The color, as first laid, is several shades darker than when dry, and to determine the finished tint, it is customary to apply a small amount of the color to some obscure part of the wall and let it dry before proceeding with the rest of the work. Then if the tint is not satisfactory, more pigment can be stirred into the solution until the desired color is attained.

153. To combine the advantages of the two modes of painting—oil and water color—many attempts have been made, either through successive processes, or the use of a vehicle of compound nature and intermediate affinity to both fluids, thence technically denominated a medium, a term

properly applicable to every vehicle. It is well, in regard to media, to note that all the gelatinous substances, hereinbefore noted as additions to water vehicles, may be combined with linseed and other oils. The compounds thence resulting may be employed as vehicles and will keep their places as delivered by the brush in painting. Starch, as prepared by the laundress, has been, indeed, lately commended for this purpose. These mixtures are, however, both chemically and mechanically inferior to the combination of lac and borax, which, equally diffusible in water and oil, does not contract in drying nor render the painting penetrable by moisture, as do farinaceous and mucilaginous substances, nor yet, in the end, dispose the work to crack. Against the proposition that artists should adopt the Indian process of painting, in which lac is rendered saponaceous and miscible in water, through the medium of borax, the foul color and opacity of the vehicle have been justly advanced.

Dissolve, however, 1 part of borax in 12 of boiling water, adding the solution in due proportion to white lac varnish, the result being a transparent, colorless liquid diffusing freely in water, which may, but not without difficulty, be used instead of oil as a fast-drying vehicle for paint. When dry, it is not removable by water. This lac vehicle is, besides, as freely miscible with oil as it is with water, supplying that true medium or connecting link between painting in water and oil, which, in ingenious hands, unites the advantages of both.

GILDING.

154. Assuming that the student has, by this time, acquired some knowledge of the painter's art and of the tools required by this form of work, demanding, as it does, attention, practice, patience, and cleanliness, there are, we need scarcely say, many ways of gilding. To one especially, known as **oil gilding**, we invite the student's attention.

The process of oil gilding is employed to beautify the interiors of private dwellings and of public buildings, all

interior work is, in fact, usually oil gilt. This method is the most commonly selected on account of its recognized wear-

FIG. 50.

ing qualities. Fat linseed oil is, for this purpose, used, mixed with finely ground yellow ocher, the older the oil the better.

FIG. 51.

The drying is to be regulated by adding small quantities of copal varnish, or Japan gold size, to be laid with great regularity and well spread out with a sable or fitch, such as shown in Fig. 50.

FIG. 52.

The gilder's tools should be in the best of order; his cutting knife (Fig. 51) scrupulously clean, as likewise his cushion, as shown in Fig. 52, which, when worn, should be recovered with soft chamois leather. The gold leaf is spread on the cushion and cut into small squares or rectangles

FIG. 53.

with the knife; a thin, flat brush called a **tip**, as shown in Fig. 53, is then used to lift the leaf from the cushion and place it upon the surface to be gilded. The tip is first drawn

across the hair or face in order to slightly moisten it so that the leaf will adhere until transferred to the sized surface.

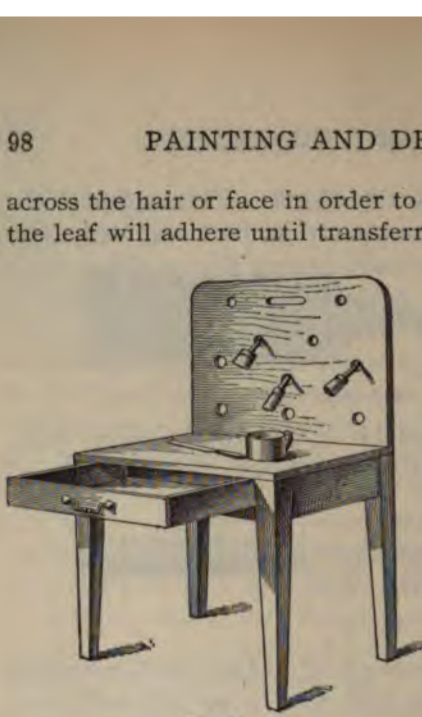


FIG. 54.

Important, also, is it that there be provided a proper platform, from which the whole ceiling may with ease be worked upon. There should also be a substantial bench or stand, such as shown in Fig. 54, placed in the middle of the room, for colors and thinnings and such mixing of tints as may be required.

Gilding is finished in two ways: **burnished bright** or **left dead.** The latter is the most usual style of decoration adopted.

155. Besides oil gilding, there is the **Japan method of gilding,** and **water gilding,** used for frames, mirrors, and console tables. Ceiling work is usually executed in oil, but may be done, wholly or in part, in Japan gilding.

Oil gilding is durable, rich, and brilliant, but Japan gilding is the more expeditious, for, as the work is not liable to **bloom,** or become clouded and discolored on the surface after drying, there is no necessity to size it after completion, as is the case with oil gilding. Japan being the best vehicle for running the lines in a design, may also be preferred for such parts as do not present a solid or rounded surface. Japan gold size is, when used alone, too rapid a drier to insure the requisite tack or adhesiveness; most gilders, therefore, add a proportion of copal varnish and a drop or two of linseed oil.

In case the lines are to be run upon a dark surface color, or in juxtaposition thereto, the vehicle should be slightly

stained by the addition of some finely ground chrome. If, however, the lines are to be run in contrast with light tints, a portion of burnt sienna should be added, care being taken that the pigment thus used is sufficient only to give requisite staining property, without affecting the adhesiveness of the gold size. The medium thus prepared, lines may with it be run by the aid of straightedge and lining fitch. Moldings, also, may be gold sized with sable or fitch. Stenciling, too, may be done, and such parts as require penciling in by hand, readily completed.

Japan size, if properly manipulated, should be ready for gilding in from one to two hours, and should, after being thus ready, hold the tack for at least an hour.

Oil size, from its liability to spread and form a ragged edge on the work, is not adapted to lining or to stenciling. Where the paint underneath is not properly hardened, the surface should, before gilding, be brushed over with white of egg and dusted with powdered whiting. This process, which arrests the adhesiveness of the paint, is unnecessary if the colors have been worked in flatting, provided the flatting itself has been properly made up.

156. Oil gold size being an expensive commodity, many gilders make their own, as being more reliable than any of the readily purchasable kinds. It is simply a preparation of fat or linseed oil, thickened by age or exposure to the sun. For this purpose the oil which collects on the top of oil paint should, after standing a few weeks, be carefully poured into another vessel. Mixed with raw linseed oil, this is placed in a large, wide-mouthed pot, covered with a sheet of glass, to keep out dust particles. This is, in turn, put where it may, for two or three months, get the direct rays of the sun, during which time it must be occasionally stirred. If water be placed at the base of the pot, such impurities as may be in the oil will sink through the water to the bottom, greatly facilitating this stage of preparation. The oil, under this treatment, will, in the course of a few weeks, attain the consistency of syrup and may be poured off into bottles.

This, again, should be heated gently until the oil once more becomes fluid, when it may be gently strained through coarse muslin, to remove the sediment, after which it is put into gallipots or covered away for use. When required for use, a proportion of yellow ocher and chrome finely ground should be added to the oil, which, if found too slow in drying, may be further implemented by a slight admixture of the better class of carriage varnish. The usual time required for it to set properly on the surface, is from twelve to sixteen hours. Properly made, it will, after it has become set, hold the tack for six or eight hours or even longer.

Turpentine should never be added to either oil or Japan gold size, as its evaporation greatly impairs the brilliancy of the gold, some work actually turning black in consequence of the use of turpentine as thinning. The best method is to thin out with oil or varnish. Oil gold size invariably tends, however, from its very nature, to produce a *ropy* surface, i. e., a surface streaked with lines of uneven thickness or body. Hence, on broad surfaces, to insure an even spreading of the vehicle, it must be carefully *laid off*.

157. Parchment Size.—To prevent blooming, the gilded surface should, on completion, be gone over with parchment size, which is made by melting parchment cuttings and diluting these with warm water. This is applied with a camel's-hair brush lightly over the surface of the gilding. The greatest care must be taken to keep the apartment free from dust, both while the gold size is wet and tacky and the parchment size is being applied or drying. Some gilders use pates or paper-stainers' size, instead of parchment. Considerably cheaper, it is, however, on account of inferior transparency, unfitted for good work. One coat of parchment size is sufficient for comparatively small surfaces, such as moldings, etc., but on a wider expanse of gilding, it is, in some instances, well to go over the surface even a third time, to make certain that the gold is fully covered, otherwise the work may, from the blooming of parts insufficiently sized, present a spotted appearance. The

parchment cuttings for the size are heated gently over a gas stove, as shown in Fig. 55, in an earthenware vessel, similar to that shown in Fig. 56, which is preferable to a metallic pot.

FIG. 55.

FIG. 56.

158. Generally speaking, it is impracticable to stencil ornamental patterns, especially those made up of minute parts, to be executed in oil size or paint. Oil size may be, indeed, used as readily as Japan gold size in exterior work well above the level of the eye, but as oil size invariably spreads under the stencil plate, the Japan is, in many cases, preferable for stenciling in gold. In the case, for instance, of an ogee molding, oil size must, of necessity, be altogether discarded, its greater bulk or consistency causing it to leave unsightly edges on the pattern, which not even careful cutting in afterwards with the ground color could effectually obliterate. Japan gold size, being, on the other hand, of a more fluid nature, will, if properly prepared by the addition of a slight modicum of good copal varnish or linseed oil, as the weather or temperature of the apartment may demand, yield work not necessarily requiring to be sized with a solution of parchment cuttings, as is the case with work rendered in the more solid vehicle of oil size.

159. Here note that while it is, in some cases, essential that painted work should be prepared by means of white of egg and whiting, so that the gold may adhere only to the sized parts, a fruitful cause of the spreading of oil size and even Japan, is that painters dust too great a quantity of whiting over the work. Some decorators rub a soft cloth over a ball of whiting and apply it with all the gritty particles to the work to be gilded. Now, if an unpleasant aftertask of cutting in rough edges is to be avoided, tie the powdered whiting in a bag made of two or three folds of the

finest muslin, removing any of the dust escaping from the meshes of the material. If the work is well covered with a solution of white of egg, the merest touch of the pounce bag should suffice. There being a reason for everything in the decorator's practice, it may be mentioned that the white of egg is used to prevent the gold leaf from adhering to the paint, and that the whiting serves the equally essential purpose of preventing the gold leaf from adhering to the white of egg. Thus it may, in a particularly hot room, happen that the white of egg may, if used with too small a proportion of water—an error to be carefully avoided—or from the extra tackiness of the ground work, prove difficult to remove, refusing, for instance, to yield easily to the persuasive influence of a soft, damp sponge. If, in such a case, the gold leaf also adheres to the white of egg, the work becomes practically worthless.

In practice, the proportion of water should be rather more and never less than 4 ounces to the white of an egg. The work upon which the gilder is to exercise his skill being then very tacky, either from the humidity of the atmosphere, or too great a proportion of oil in the preparation of the color, it is best to defer, for a few days, the commencement of operations. If the egg be too weak, the gold will stick to the work; if too strong, the egg will remain where the gold is washed off, and the work found streaked in all directions with marks from every hair composing the tool with which it may be applied.

160. Without attempting to lay down any hard and fast standard of good taste in the use of gold leaf, it may be truly said that work otherwise good is as often marred by the abundance as by the poverty of the precious metal's display.

Where it is sought to introduce gilding as an aid to decorative detail on the woodwork of an ordinary apartment devoted to living purposes, the wall paper should be taken as much into account as the painting of the woodwork. Because the wall paper happens to be of a certain tone, it does not follow that the painted work must match it. Neither must it be supposed that a wall paper, relying for

effect upon metallic details in the design, needs the support of a quantity of gilding on the painting placed in juxtaposition with it. If, on the contrary, the walls have a mass of metal or gold, as the paper stainer generally terms it, introduced into their hangings, it is often better to dispense with gold in the woodwork, or to apply it so sparingly that the eye may find the repose so essential for appreciation and enjoyment. A mass of gilding on ceilings, walls, and woodwork often has, in an apartment illumined by artificial light, an effect painful rather than pleasing, all being garish glitter rather than the calm and dignified harmony resulting from embellishment by a decorator of cultivated taste.

161. Where, for instance, the ornament on a door panel would be lost in the effulgence of a profusely decorated molding, gild only the narrow fillet next the panel, painting the body or carved portion of the molding in some harmonious tint. Waste of gold leaf is thus prevented, to say nothing at all of the greater facility with which oil size can be run upon the narrow flat by an expert pencil hand, holding lightly between the thumb and forefinger (Fig. 57) a striping brush,

FIG. 57.

such as shown in Fig. 58. If, on the other hand, the molding of the door panel be exceptionally broad, and it be desirable to break the solidity of its appearance, cut on a stencil paper some simple ornament, such as a succession of triangular notches, the dog's tooth, or any running ornament of not too complex a character. Its rendering in gold on the molding, although the time taken be somewhat in excess of

that needed to gild the whole member, will yield an artistic effect, in the precise direction intended. No saving of gold

FIG. 58.

will, indeed, be effected, for the gilder must, of necessity, cut his leaves into sections, each the actual width of the molding. But the surplus gold leaf, removed in the usual manner, first by the dabber, and finally with cotton wool, will add to the value and quantity of **skewings**, as the surplus gold leaf is called, and in some measure compensate for the additional labor.

Haste, and the crowding together of two or three different sets of workmen in the same place and time in which gilding is under execution, are conducive to wastefulness and inefficiency. The skilled decorator will, therefore, make due provision to enable his gilders to pursue their work with the facilities insured by freedom from interruption and such like inconveniences.

162. Fig. 59 presents us with a door proposed to be finished in white and gold. When the paint is thoroughly hard, the parts to be gilded are judiciously selected. We may, in passing, remark that the transom light in the engraving bears a heraldic design, which should be embossed on the glass.

The members to be gilded are the fillet, bed moldings, and labyrinth or fret *a*, *b*, *c*, *d*; the key block or truss with the bed molding and two bands forming side scrolls *e*, *f*, *g*; the fillet and bead of the architrave *h*, *i*, *j*; the raised ornament on the spandrel panels *k*, to be heightened on the edges only; the transom-bar cornice, fillets, and bed moldings *l*, *m*, *n*; the abacus and volutes *o*, *p* on cap of pilasters, the stalks of the acanthus and the edges of the serrated leaf are also to be gilded; the fillet or neck moldings *q*; the bead molding in the pilaster panel *r*; the base or torus molding *s*; the door-joint strip with central and side strips *t*; the door panels *u*, *v*; the chamfer *w*. After gilding, a weak parchment

size is applied, care being taken not to run over on the surface of the white paint.

Fig. 59.

163. Another design, in which the stencil plate and hand penciling may be utilized together with the happiest effect, appropriate to a boudoir or small drawing room is, in the hands of an intelligent artisan, readily producible.

The door itself is enriched with shelf and ornamental backing, giving scope in style for simple stenciling or hand-painted ornament. If finished in pale blue, the most desirable color

for the more prominent members of the architrave, is a deeper shade of broken blue tone, i. e., blue slightly tinted with burnt sienna or lake, to impart warmth and obviate too crude a distinction between door and wall. The panels might be a broken white or a subdued cream tint, or if a bolder contrast be aimed at, a decided pink tone, composed of crimson lake, burnt sienna, and white lead, the lake alone, as an addition to white, being too vivid for the purpose. The molding of the panels may, in this case, be white or maroon, either extreme being effective. The free flowing and quasi-natural character of the ornament demands a rendering in maroon upon a pink ground, but blue green, not too deep in tint, may, if more closely approaching the general style of ornamentation employed, be preferable. Vases suggesting the main design may be put in a maroon tint enriched with gold, the lines in the panels being also rendered in maroon or a light shade of brown, to harmonize more equably with the ground surface. A dot of gold in the center of each flower emphasizes the general effect. Details of the enrichment of cornice and entablature may be in gold and maroon, or white and gold, according to the choice made for the panel moldings. The dado may, if done in wood, be treated similarly, and all added ornament should partake of the same general character as the door panels. The skirting should be brown, or at any rate much deeper in tone than other portions of the work.

164. Another method of treatment suited to a bedroom could not fail of yielding happy results, in color effect. Let the wall paper, for instance, be a pale cream ground with a pattern of pale greens, pale yellows (approaching ocher in hue), and pink; below this a dado of purple tone with a suitable band on a green ground. Now let the outer architrave be a pale creamy blue, composed of white burnt sienna and Prussian blue, the detail cut in with brown or Indian red. Then paint the panels in a green tint several shades darker than the circumjacent colors, imparting to the stiles and architraves colors none too light, but relieved by the addition

of burnt sienna insufficient in quantity to decidedly stain, but enough to subdue the brilliancy of the green. From what has been already stated in this paper, it may seem hazardous to place green and blue together. Experience often, however, modifies theories. If, in this case, a practical man judiciously combines these colors, he will certainly prove the pleasing nature of the combination. Next reproduce the foliated design and the lines on the panels in a warm, straw color, compounded of ocher, chrome, and sienna, reduced to the proper tint by admixture with white. On the stiles which, like the architraves, are of creamy pale blue, place some maroon or Indian red lines corresponding to each panel and run the moldings in white, or, reversing the method, run the lines in white on the pale blue ground and define the moldings in maroon, reduced in strength of shade when the whole member is run in solid. Finish the skirting in appropriate tones. Stenciled designs may be made a ground for hand painting in natural tones, by putting it on the work in some gray tint and proceeding as if the whole had been rendered with the pencil exclusively. Flowers and leaves, stems and sprays and vases may all be admirably and with surprising facility rendered, while a butterfly or some such suitable specimen of insect life, here and there added, gives the design a winsome effect.

PAPER HANGING.

165. The art of paper hanging is easily acquired, but the tasteful choice of paper for various situations is a gift of no such easy acquisition. The walls of a room should be regarded as the mere framework of what the room is to contain. Their decoration should, therefore, bring into prominence rather than eclipse the contents of the apartment. Wall paper of glaring color and gaudy ornamentation brings into the utmost conspicuousness that which should be an accessory.

In a modern drawing room the ceiling should be tinted a color harmonizing with the wall paper, as no harmony can

be hoped for when its main constituents are surmounted by the glaring white of an ordinary ceiling. The tint used must be one that softens into the wall paper, not one that contrasts; thus, if the tone of the room is that of a soft gray blue, the ceiling may be a clear flesh pink, or, if a gray, green paper, picked out with black, be the wall color, the ceiling may be of subdued lemon.

The ceilings are, in some cases, covered with a whole colored paper, bordered with a stencil pattern, representing thin garlands, but this is a more labored method than the simple coloring which answers the same purposes. The walls, if lofty, require a wide frieze, which gives an appearance of comfort—absent from the modern high-ceilinged room, papered in one uniform pattern. The frieze is divided from three to four feet from the ceiling, the coloring of the lower being, of necessity, heavier than that of the upper part, otherwise a top-heavy aspect is given the room.

When many pictures are to be hung, the lower part of the frieze should be of a whole color, for it is only on a whole-colored paper, or painted wall, for a background, that pictures can show to advantage.

When a whole tint is used for the lower part of the frieze, the upper portion should be decorated with a frieze paper of a good bold pattern, of coloring not too pronounced, and of a tint harmonizing with the lower section. Contrasts must be carefully avoided, but pale pink, blue, and amber can be blended above a subdued gray-blue ground. The two portions of the frieze should be separated with a light wooden (black or brown) molding or with a line of paint. The frieze decoration can be altered by placing the pattern upon the lower part, leaving the upper plain colored with or without a stenciled pattern. This will suit a room where few pictures are required, or one disposed to be dark. Some part of the wall should always be in plain color, as the eye requires rest; and no pattern, however subdued in hue, can give the relief to the eye that a bit of plain coloring affords.

This scarcity of ornament in one part of a room is amply compensated by the effect it gives to such parts as are bright,

and rightly should be so. The true theory of effect is to use but one or two bright colors in a room, surrounding these with soft and subdued tints that do not impair, but emphasize the brilliancy. A number of bright colors placed together destroy each other's naturally pleasing effect, leaving no impression on the mind but glare and vulgarity. Having settled upon the paper and ceiling, have the woodwork and cornices of the room painted either a shade lighter or darker than the walls. The background of the room thus complete, the furniture will look much better than if stared out of countenance by glaring walls.

166. To prepare the walls, make a size of glue and water and heat in a kettle, such as shown in Fig. 60, over a charcoal stove, a form of which is shown in Fig. 61. Then give the

FIG. 60.

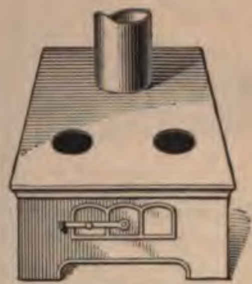


FIG. 61.

walls a coat of a very weak solution of the same, with a broad, flat brush, such as shown in Fig. 62. To make a paste, take 2 pounds of fine flour, put in a pail, add cold water, and mix it together in a thin dough. Take a piece of alum about the size of a small chestnut, pound it fine and throw it into the paste; mix well. Then pour in about 6 quarts of boiling water, mixing with the paste while hot until the whole is brought to a proper consistency; use when cold.

FIG. 62.

The walls should be thoroughly dry before the paper is hung. The surface of walls, prepared for the first time, should be stopped, rubbed smooth with a piece of pumice stone, and then treated with a coat of size as before men-

FIG. 63.

tioned, which prevents the plaster from absorbing the paste. In order to obtain a smooth surface, a plain, coarse, white lining paper is sometimes hung first. In hanging lining paper, the edges of adjacent pieces overlap about $\frac{1}{4}$ inch, and are distempered and well rubbed down, to prevent their showing through the wall paper. Common papers are hung with the lap of their trimmed edges facing the light, so that

they may cast no shadow. The finest papers are hung edge to edge, or butted together, and where the walls are damp, canvas may be stretched tight over battens or furring strips, nailed to the plaster so as to leave an air space between the walls and the paper. This method has, however, disadvantages, as the canvas expands and contracts with changes in the weather. When it is, however, resorted to, the heads of the nails securing the canvas should be covered over with strips of common paper before the wall paper is hung, but if the nails be of iron they should be painted. In ceilings, the edges of the paper should run at right angles to the principal light of the room.

In papering a wall, the preparatives just described having been attended to, the paper is trimmed and the paper hanger plumbs the wall, so as to hang the paper in perfectly vertical strips, as shown in Fig. 63. After hanging the paper, he should smooth it down with a smoothing brush, as shown in Fig. 64, to cause it to adhere to the wall surface, throughout its entire length.

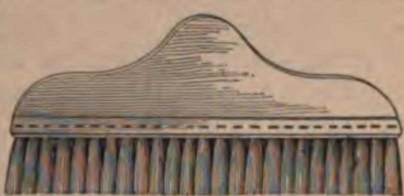


FIG. 64.

167. In cases where a varnished paper is required for certain walls, such for instance as those of a nursery, or bath room, or of narrow passages, or for the walls of more important rooms, the wall paper may be given two coats of sizing and then varnished in two coats or more. The second coat of sizing is applied to make sure that the surface of the wall paper is entirely covered. A washable varnished paper is, however, manufactured and easily procurable.

The preparation of the size for varnished paper varies according to the quality of the glue used. If the best white glue is used, we would advise $\frac{1}{4}$ pound of glue to 1 gallon of water as follows: Place the dry glue in a vessel, covering it with water. When the glue has become soft and pulpy, take it up in the hands, squeeze out the water, and then boil over

the fire, placing the vessel containing the glue into a larger vessel containing hot water, the object being not to burn the glue or size, by placing it directly over the fire. The glue thus melted is then mixed in a gallon of boiling water, and having been allowed to cool is ready for application to the wall. If, in applying the size, it is found that the colors in the paper rub up, the first coat of size must be sprayed on with an atomizer. The varnish used is known as dammar or light enamel varnish (Art. 84).

168. Repapering.—In repapering walls, the old paper should be removed, the wall scraped, washed, stopped, and coated with size. If the old paper cannot be removed without injury to the wall surface, a coat of size should be applied to it and over that a coat of whiting and size, or distemper. A strong objection against the retention of old paper is that it is likely, through the decomposition of the paste securing it, to prove injurious to health.

169. All domestic wall paper comes in double rolls, of 16 yards in length, and either 18 or 22 inches wide. Cartridge or felt papers are 30 inches wide and 16 yards per roll. Borders are from 18 to 22 inches wide, the same as the papers they match. Imported wall paper is 22 inches wide, but runs only 12 yards to the roll.

GLASS.

PLAIN GLASS.

170. Classification of Glass.—It is a part of the painter's province to be familiar with the different kinds and qualities of glass, as well as with the general methods of its manufacture, that he may judge of those best suited to the purpose required, and know the available market sizes to be readily obtained. All glass is composed of three chemical elements, i. e., silica, soda, and some metallic oxide. These are mixed in varying proportions to suit the requirements of each case, and sometimes receive some

additional element to vary the color or degree of transparency of the finished product. The principal properties upon which the value and utility of different kinds of glass depend are: transparency, fusibility, and viscosity at a red heat, whereby it may be molded into any desired form. It is not necessary that the student should know the exact nature of the constituents of all the different forms of glass, but a knowledge of the methods of manufacture will be of great assistance to him in determining the kind and quality of glass upon inspection, or in deciding upon the precise kind best suited to some particular purpose.

There are three general varieties of glass used in architectural work; namely, **crown glass, sheet glass,** and **plate glass,** each used under certain conditions, limited by the character of the work and the details of the manufacture of the glass.

171. Crown glass is made by dipping the end of a long iron tube, called a blowpipe, into the melting pot, and collecting thereon a lump of semifluid glass, which is then extended into a large hollow globe, as shown in Fig. 65, by blowing through the tube. The globe is then again heated while it is rotated rapidly and spreads out into a large flat disk, called a "table," under the influence of the centrifugal force of rotation. This naturally causes the glass to become gradually thinner towards the edge, while at the center is a large boss, or bulb, where it was attached to the rotating tube. In cutting the glass into panes, this boss must be cut out and thrown in the waste pile to be remelted with the next charge in the pot. The remainder of the table will, under favorable circumstances, make about 13 square feet of window glass, but if cut in large size panes, only 10 or 11 square feet can be secured. The largest available panes of crown glass are about 25 in. × 33 in., but are so warped or curled, owing to the original globular shape from which they are formed, that they must be flattened before being put on the market for use. This flattening is

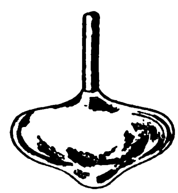


FIG. 65.

accomplished by heating the glass to a red heat and letting it lie on flat slabs to cool. The smaller sizes do not usually require flattening, the amount of curl in them being so slight as to be scarcely noticeable.

Crown glass is put on the market in two thicknesses; the thinner brand, called **ordinary,** being about $\frac{1}{20}$ inch thick and weighing 10 ounces per square foot, while the **extra** or heavier quality is about $\frac{1}{16}$ inch in thickness and weighs 16 ounces per square foot. These qualities are packed in crates, the contents of which vary in amount, according to the thickness and form of the glass. A crate of ordinary quality should contain 18 tables or 36 panes, the latter averaging 23 inches in width, while a crate of *extra* usually contains 12 tables or 24 panes of about the same size. The available length of these panes varies with the width, but no single sheet can be obtained of greater area than 5 square feet. Crown glass is classified in five qualities, only three of which are used for general building purposes. These are **best,** used for first-class dwellings; **seconds,** used for cheap dwellings; and **thirds,** which are of little use except for barns and outhouses. Crown glass is more transparent than either of the other varieties, but the fact that it is available only in small panes so limits its use that sheet glass has superseded it for general building purposes.

172. Sheet glass is gathered and blown similarly to crown glass, except that after the globe is formed, it is rolled in a molding block and the blowing is continued until the glass takes the form of a long hollow cylinder as shown in Fig. 66. The end of this cylinder is then reheated and opened as shown in Fig. 67, while the cylinder is rapidly revolved until the edges flare out and extend the sides to the edge, which is then cut off with a pair of scissors while the glass is still hot, the cylinder then assuming the form shown in Fig. 68. The cylinder is allowed to cool and then detached from the blowpipe, by placing a hot wire or bent rod around its upper end, as shown at *a*, the wire being held by the loop *c*. The edges are then rendered parallel and

true, by placing the cylinder in the trimming machine shown in Fig. 69. This consists of a pair of clamps on a perpen-

FIG. 66.

FIG. 67.

FIG. 68.

FIG. 69.

dicular rod, against which the cylinder is held with one hand, while a moving diamond is passed around the bottom and

cuts the glass off perfectly even and straight. The cylinder is then transferred to the splitting block shown in Fig. 70, where another diamond moving in a horizontal guide cuts the cylinder down one side parallel with the axis. It is now transferred to a flattening kiln, where, under the influence of heat, it gradually opens out and unrolls until it becomes a

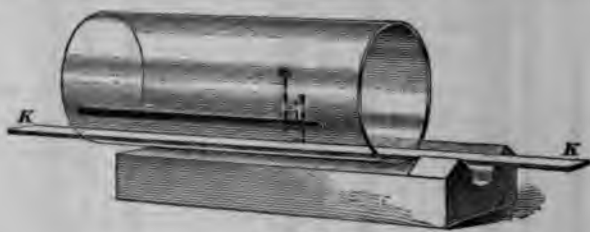


FIG. 70.

flat pane of glass. When cooled sufficiently to handle, it is cut in panes and packed for shipment. Sheet glass is used for building purposes in three qualities, similar to crown glass; namely, **best**, **seconds**, and **thirds**, and each quality is applied to similar purposes as the same named quality of crown glass, but they are all available in much larger sizes than crown glass, and in six thicknesses from $\frac{1}{16}$ inch to $\frac{1}{8}$ inch, and varying in weight from 15 ounces to 42 ounces per square foot. Every $\frac{1}{16}$ inch in thickness adds 13 ounces to the weight per square foot.

173. The largest sizes available in sheet glass are as follows:

Weight. Ounces per Superficial Foot.	Maximum Length. Inches.	Maximum Width. Inches.	Maximum Area. Square Feet.
15	55	38	13
21	85	49	22
26	85	49	22
32	85	49	22
36	70	44	19
42	70	44	19

These sizes are governed by the maximum area of the blown cylinder. A sheet may be of the maximum length or the maximum breadth as shown above, but no combination of length and breadth can be obtained which will exceed the area given in the last column, and any size larger than 36 in. × 50 in. is subject to a special price above the regular market quotations. Sheet glass is sold in crates, the contents of which vary according to the thickness of the glass. A crate of 15-ounce glass contains 40 sheets of stock sizes, while 21-ounce glass and 26-ounce glass run 34 and 28 sheets to the box, respectively.

Sheet glass has, as before stated, very largely superseded crown glass for window glazing on account of its availability in larger openings; but, besides this advantage, it is free from the wavy undulations prevalent in crown glass, and recent improvements in its manufacture leave little difference in its comparative transparency. Sheet glass is sometimes polished as described hereafter, and when so treated is called patent plate, to distinguish it from the ordinary polished plate described below.

174. Plate glass is manufactured by a process totally different from either of the varieties already described, the essential difference lying in the fact that it is cast and not blown in the required form. For this reason plate glass is always much thicker than blown glass and often lacks the transparency attained by the other methods; besides this, it is likely to contain air bubbles and other imperfections, and only selected pieces can be used for window glazing. The melted glass is poured on a long cast-iron table, over which a heavy iron roller is passed by means of cog wheels. The glass is thus squeezed out before the advancing roller and pressed into a sheet, the size of which is limited only by the length of the table and the width of the roller. The thickness of the sheet is regulated by strips of metal laid along each side of the table, on which the roller bears and by which the width of the sheet is regulated. After the rolled plate is cool enough to remove from the casting table, it is carried

to the annealing oven and there permitted to remain for several days, where, under the influence of a high temperature, it softens, becomes more homogeneous in composition, and less likely to crack or break under subsequent changes of temperature. The sheets or plates, when removed from the annealing oven, are not smooth and transparent like the finished products of blown glass, but have an irregular, rough, undulating surface, and are used only for skylights and floor lights under the name of plate glass.

175. Polishing Glass.—When the plates are withdrawn from the annealing oven, they are carefully examined for any defects, such as air bubbles, opaque spots, etc., and those plates which are free from imperfections are selected and set aside for polishing. This is accomplished in three operations: namely, grinding, smoothing, and polishing. The grinding and smoothing table consists of a revolving slab, with a bar fixed horizontally, about 10 inches above its surface, to which two iron runners are attached. The glass to be ground is cemented to the table with plaster of Paris and the runners set to rest evenly on its surface. This apparatus is shown in Fig. 71, where the slab or table is seen at *a*; the runners at *b* are pivoted at *e* to the fixed rod or bar *c d*, when the table is revolved by machinery. The runners are independently revolved on their bearings *e*, and being fed with emery or sharp sand and water, every part of the plate is evenly abrased and the surface is ground down until perfectly level and true. The smoothing process is conducted on the same table and in the same manner, but the runners fed with a finer grade of emery,

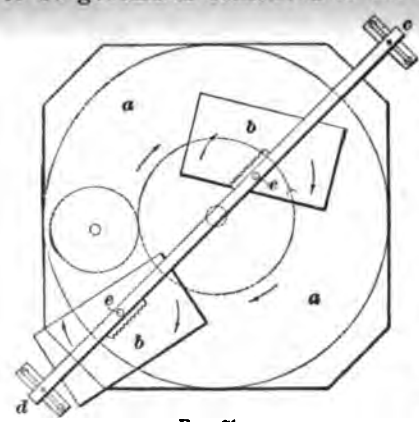


FIG. 71.

which renders the surface of the plate perfectly smooth, but not transparent. When both sides of the plate are ground and smoothed, it is removed from the table and polished with felt rubbers, supplied with jewelers' rouge and water. This operation removes every trace of abrasion by the sand or emery and leaves the plate perfectly clear and transparent, but about 40 per cent. less in thickness than when it left the annealing oven. Ordinary finished plates vary in thickness from $\frac{1}{4}$ inch to $\frac{3}{8}$ inch, and may be obtained in regular sizes up to 17 ft. $\times$ 9 ft. 6 in.

176. Rolled plate is a form of unpolished cast plate glass used largely for floor and vault lights, the only difference between this and the regular unpolished plate is that the roller used to spread the semifluid glass, on the casting table, is cut in grooves or squares which mark the glass correspondingly, causing it to cool with a ribbed surface or with a diaper design on one side.

177. **Colored glass** is produced by adding various chemicals to the melting pots, while the glass is in a state of fusion, and may be made under any of the processes heretofore described. Colored crown or sheet glass is of two kinds, known as **pot metal** and **flashed colors.** The first is made by dipping the blowpipe in the pot of melted glass and blowing the globe or cylinder as described in Art. **171.** The glass is therefore uniformly colored all the way through its thickness. Flashed color is produced by dipping the blowpipe in clear glass first, and then, before the globe is blown, covering the lump of glass accumulated on the end of the pipe, with a thin layer of colored glass, by dipping it in a pot of colored metal. When the globe or cylinder is then blown, the colored glass spreads evenly over the exterior, and the finished sheets or panes are of plain glass, with a thin veneer of color. Flashed color may be applied to both sides of the glass, by dipping in the colored metal first, then dipping in the clear glass, and again coating the plastic lump with a layer of colored glass. When the globe or cylinder

is then blown, we have a tinted film on the inside and another on the outside, with a colorless layer between. When this is opened out to form tables or sheets, both sides of the panes have a veneer of colored glass. Colored plate glass can be made only of pot metal, and, owing to the expense of polishing, it is seldom made except in the form of unpolished plate. This is usually called **cathedral glass**, on account of its extensive use in church windows, etc.

ORNAMENTED GLASS.

178. Painted Glass.—The manufacture of colored glass, the basis of the refined and interesting art of glass painting and staining, dates from times remote. The use of enamels to variegate or ornament glass surfaces, was known to the ancient Egyptians, but the construction of windows made of mosaics of colored glass, bearing figures or ornaments emblazoned with an enamel fixed by fire, is medieval and decidedly a Christian art. It was, in all probability, suggested by the mosaic pictures with which, from an early period, churches were adorned for the instruction of the illiterate. From mosaic pictures to glass mosaic windows is, in truth, a step only, but when taken is not definitely known. Certain it is, however, that as early as the sixth century, colored windows adorned the Church of St. Sophia at Constantinople, and the basilicas of St. John Lateran and St. Peter of Rome. Wilfred, Bishop of York, in 709, invited to England workers in glass from France. The French, indeed, claim the honor of having invented the process of painting upon glass and carrying their invention to the English, who, in turn, instructed the Germans.

The first attempts at glass painting were made by forming pieces of colored glass in figures and painting the shadows of the draperies and other parts with a brush in a vitrifiable or enamel black, reddish, or bister color, which was afterwards fixed in a furnace. Painted figures of the twelfth and thirteenth centuries are all executed in this way, besides

being alike in other respects. Various local colors are imparted by the several fragments of variegated glass; this species of glass is known as semipainted. The art of glass painting, today, not only possesses the excellence of times past, but enjoys, through progress in the science of chemistry and in the arts of design, an esthetical power far exceeding that of former ages, and is, with happy results, devoted to other classes of ornamentation besides those of a purely ecclesiastical character.

179. Patterns in Leaded Work.—Fig. 72, illustrating the elementary principles of *leading* practised in early times, represents diamonds, or lozenges, and is one of the earliest patterns known. Later, a small geometric pattern, painted in the middle of each piece of glass, was added, the color being dark reddish, giving a pleasing, diaper effect, while the pattern consisted, in the main, of conventionalized foliage, covering two-thirds of the surface of each lozenge.

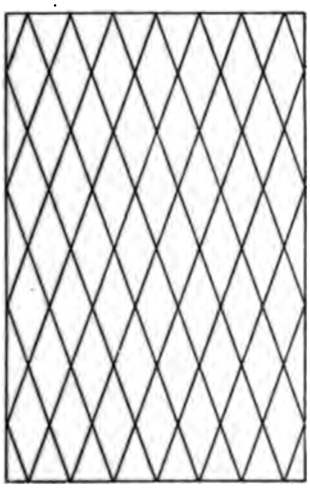


FIG. 72.

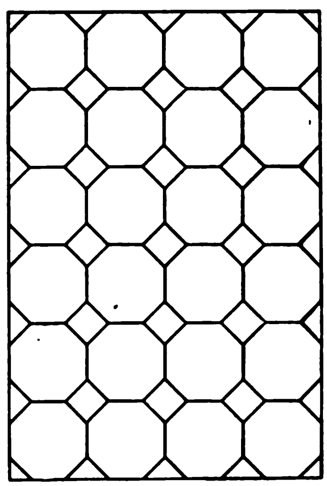


FIG. 73.

Fig. 73 is an octagonal diaper, with lozenges interspersed between the octagons. It is another early form of leaded work composed of straight lines only. Fig. 74 is composed

of curvilinear forms, made up of segments of circles and curved lines only. It is usually made of crackle and wavy white glass.

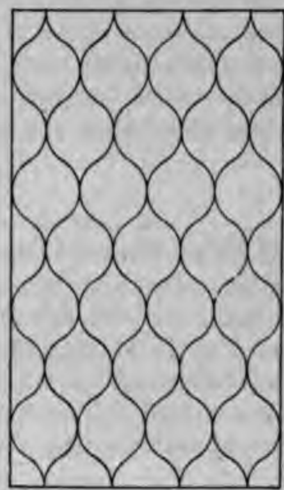


FIG. 74.

FIG. 75.

Fig. 75 presents a form of leaded window, composed entirely of curved lines, circles, and semicircles arranged in a foliated pattern. Dating from a much more recent period than the styles represented by Figs. 72, 73, and 74, it shows the progress from the early geometric forms towards the elaborate designs of the present day.

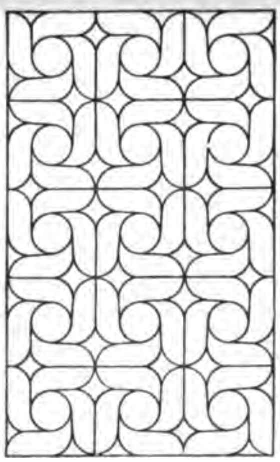


FIG. 76.

Fig. 76 is a diaper composed of straight and curved lines, circles, and semicircles. This is a geometrical pattern drawn by the aid of squares, a circle being struck from the four corners of each square. For its manufacture the same materials used in the case of Fig. 74 may be employed.

Fig. 77 offers a design of modern origin for a hall window. It consists of a richly colored ornamented border, the panel divided into three parts, with a lozenge-shaped pattern, each diamond in turn divided into four smaller diamonds. The upper portion of the panel, nearly one-half its whole length, bears a shield supported on either side by flowing ribbons, whereby trophies are attached to the top or

FIG. 77.

FIG. 78.

back of the shield. The lower section of the panel is filled in with stripes of vertical glass, fitting into the angles formed by the cross-band of lozenge-shaped pieces. Such a window may be constructed of plain colored and wavy glass.

Fig. 78 shows an oblong panel, whose border is of an interlacing pattern enclosed with a strong line, the inner panel

divided into three sections, that in the center being a beveled plate of clear glass, with an interlacing section above and below, shown in the figure. This panel may be constructed of pieces of colored glass and wavy white glass.

Fig. 79.

Fig. 79 represents a window, or door panel, with a narrow border and a broad band at each end, the latter containing circles. The panel is adorned with a heraldic design, whose shield is surrounded by a cloak and topped with a knight's helmet, surmounted, in turn, with a crown celestial. The remainder of the panel field is filled in with irregular pieces of tinted wavy glass.

180. Painting Glass. The process of laying the color on the glass varies according to the different descriptions of glass painting which first call for explanation. The colors may be laid upon a single sheet of glass on which the whole figure, with its principal and intermediate tints, are burned in. Or, the figure may be composed of various pieces of pot metal, with the outlines and shadows only painted on, the pieces of glass just spoken of giving the colors for the different places they are to fill in the mosaic glass painting. Again, both methods may be combined, and the same figure composed, in part, of pieces of pot metal, and, in part, of white and painted glass set together.

For painting on a single sheet it must be observed that a

pure white glass, free from air specks or air bubbles, and hard of fusion, must be selected for the purpose. The artist's labor would be entirely lost if he attempted to burn in colors on a surface as readily fusible as the colors themselves. The example of the ancients, however, proves it practicable to paint with good results upon very common glass, free from an excess of lead, rendering it too fusible. Before being painted upon, the glass should be rubbed with pure lime, slaked by exposure to the air, which cleans it perfectly. The surface of the glass is then prepared by spreading evenly all over this surface a thin coat of common paste, or a thin, clear ground of black glass-painting color, so as not to destroy the transparency, but give it the appearance of a dead ground glass. Each method covers the glass with a viscous surface, which receives the color and design better than could a polished surface. The ground thus prepared must then be carefully stippled with a large badger, brought to as thin a surface as possible, dried quickly, and kept free from dust. The sheet of glass thus prepared, may be laid on a drawing of the figure required, and the outline, as seen through the glass, traced lightly with a fine pencil in black or other glass color like the ground. Or, the pattern may be reversed on the glass, but in this event the back of the drawing must be rubbed over with dry white or some other color, a steel or ivory point being called into requisition to transfer it to the surface of the glass. The drawing, whether placed over or under the glass, must be fastened at each corner with wax. The glass is then placed upon the easel, that the light may easily shine through it, but is sometimes, to better bring out the effect of the colors, removed from the easel and laid upon a sheet of white paper.

181. Oil is the usual vehicle with which pigments are laid on glass. Some artists, however, use water alone, but water alone is an insufficient medium for binding the metallic bodies to the glass, particularly if, as in the case of fused colors, they are coarse in texture and require to be laid on in thick layers. These applied with a water medium only,

easily loosen from the plate before fixing, and render the process of laying on much more difficult. An important advantage of the oil medium is that the edges may be more sharply defined, and the parts already painted gone over again when dry, without loosening the previous painting. Oil of turpentine, thickened by exposure, is the most suitable oil for use, giving the necessary degree of viscosity and preventing the colors from drying too quickly on the palette (which for this work should be of thick plate glass or porcelain, ground on one side).

182. There are three principal methods of painting on a single sheet of glass. The whole picture may be brought either in outline or in shadow on one side of the sheet, with black, brown, or gray color, and with appropriate tints illuminated in the proper places on the opposite side; or, the artist may make use of both methods combined, employing each in certain places, according to the requirements of the situation. The outline and shadow and the **underpainting** in oil should be executed on the side of the glass to be turned towards the spectator, while the illuminating colors are laid on the reverse side.

183. Stained glass must not be confounded with painted glass. The coloring in stained glass is either a superficial layer or pervades the substance of the glass, and is obtained by applying a coat of metallic oxide. The art of joining together small pieces of stained glass to form colored designs or transparent mosaics was practised in classical times. But, though the ancients were fully acquainted with the art of coloring glass, the fragments of ancient window glass hitherto discovered are all devoid of color. Glass staining may be defined as the art of applying to transparent glass, colorless or colored, in the process of its manufacture, metallic colors, afterwards burnt into the surface of the glass on which they are laid. All colors used in glass staining are oxides of metals or other metallic combinations, and may be divided into two principal classes: (1) those whose coloring basis—the oxide—is laid on the glass

simply in an original combination with an earthy vehicle; (2) those whose coloring or oxide is made to adhere by the aid of a glossy body, viz., the **flux**, a vitreous compound fusing at a lower temperature than the foundation, or glass plate.

The colors requiring the flux may be again divided into two classes: (1) those in which the oxide requires to be vitrified by previous fusion with the flux before it is laid on the glass; and (2) those in which the oxide and flux are mixed together and fused when the color is baked into the glass during the process of firing. The first may be called *fused* colors, all others *mixed* colors.

This classification may be more readily grasped by bearing in mind that glass staining is distinguished from other illuminating processes, in that the colors and the foundation on which they are laid must, in this art, be fused together in the kiln.

Some few colors, without any previous preparation other than the simple laying on, combine with the surface of the glass at the temperature of fusion, and, therefore, impart to the glass a coloring cementation or stain only. Others, on the contrary, can only be brought, in consequence of their peculiar nature, to combine with the glass by being fused into another thin sheet or layer of colored glass, upon its surface. This is done by means of the flux.

The flux may be used in two ways: First, with some colors, it may be mixed before they are laid on, combining with their oxides at the temperature of fusion, uniting these, again, with the surface of the glass; second, in other cases, the flux must, before staining, have entered into a chemical combination with the oxides, i. e., by being fused together with these, to produce what is termed a fused color, which, after being pulverized, serves as a pigment. This process is rendered necessary by the difficulty of fusion in certain oxides, which, to combine with the flux and acquire the intended shades of color, demand a greater degree of heat than that available in burning colors upon the glass, without endangering the success of the operation.

184. From consideration of the nature of the colors and their combination with glass, we proceed to give the following tables:

RECEIPTS FOR THE INGREDIENTS OF COLORED GLASS.

Mixture for Rose-Colored Glass.

	PARTS.	OR	PARTS.
White sand	100	White sand	100
Potash	48	Minium	78
Slaked lime	8	Caustic potash	35
Purple of Cassius	6	Nitrate of potash	7
Peroxide of manganese	4	Purple of Cassius	8
		Peroxide of manganese	4
		Sulphuret of antimony	4

Mixture for Red Glass.

	PARTS.		PARTS.
White sand	100	Purple of Cassius	12
Minium	60	Peroxide of manganese	6
Caustic potash	30	Sulphuret of antimony	6
Nitrate of potash	5		

Mixture for Yellow Glass.

	PARTS.	OR	PARTS.
White sand	100	White sand	100
Potash	50	Minium	80
Slaked lime	8	Caustic potash	36
Antimony yellow, colored with oxide of lead	6	Crystallized nitrate of potash	12
OR		Antimony yellow, colored with oxide of lead	8
White sand	100		
Potash	40		
Lime	10		
Antimony yellow, colored with oxide of lead	10		

Mixture for Blue Glass.

	PARTS.
White sand	100
Minium	150
Caustic potash	35
Calcined borax	10
Oxide of cobalt	4

OR

	PARTS.
White sand	100
Minium	80
Caustic potash	40
Nitrate of potash	8
Oxide of cobalt	1

Mixture for Green Glass.

	PARTS.
White sand	100
Refined pearlash	50
Slaked lime	8
Green oxide of chromium	2

OR

White sand	100
Refined pearlash	50
Slaked lime	9
Yellow oxide of antimony	4
Oxide of cobalt or zaffre.	2

OR

White sand	100
Minium	75
Calcined potash	38
Nitrate of potash	4
Green oxide of chromium	2

OR

	PARTS.
White sand	100
Minium	60
White pearlash	40
Oxide of arsenic	6
Glass of antimony	9
Oxide of cobalt	5

OR

Whitewashed sand	100
Minium	85
Calcined potash	38
Nitrate of potash	8
Yellow oxide of antimony	4
Oxide of cobalt	2

Mixture for Violet Glass.

	PARTS.
White sand	100
Pearlash	48
Slaked lime	7½
Oxide of manganese.	4 to 10

OR

	PARTS.
Whitewashed sand	100
Minium	78
Calcined potash	35
Crystallized nitrate of potash	8
Peroxide of manganese	1 to 2

Mixture for Black Glass.

	PARTS.	OR	PARTS.
White sand	100	White sand	100
White pearlash	66	Minium	82
Slaked lime	8	Calcined potash	38
White glass, pulverized	70	Nitrate of potash	8
Oxide of arsenic	6	Oxide of cobalt	8
Oxide of cobalt	10	Peroxide of manganese	8
Peroxide of manganese	10	Black oxide of iron	12
Acetate of iron, or iron in the highest state of oxidation	5	Oxide of copper	12

Mixture for Opalescent Glass.

	PARTS.		PARTS.
White sand	100	Hydrochlorate of silver	10
Refined pearlash	50	Phosphate of lime from mutton bones	60
Slaked lime	16	Oxide of arsenic	30
Calcined, or white broken glass	500		

Mixture for White Opaque Glass.

	PARTS.		PARTS.
White sand	100	Slaked lime	16
White pearlash	66	Oxide of tin	60
Slaked lime	8	OR	
White glass, pulverized	50	White sand	100
Oxide of lead	100	Minium	78
Oxide of arsenic	3	Calcined potash	30
OR		Nitrate of potash	30
White sand	100	Nitrate of potash in crystals	8
Calcined potash	50	White oxide of tin	62

185. The **cartoon** is drawn with a stick of charcoal full size on paper strained on a frame of equal dimensions with the window opening, making a strongly defined outline and

clearly indicating the lines to be leaded around each piece. The designer, before commencing to use the charcoal, prepares the paper with a coat of glue size; when the picture is complete, the charcoal drawing is fixed on the sized surface, by steaming the picture all over with the steam kettle. Each separate portion of the subject is, for the glazier's benefit, numbered, before the cutting of the different pieces of glass is proceeded with. The cartoon is then laid down upon a large table, the painter lining out in color the different pieces, or, in other words, tracing the drawing with a strong white or black line about $\frac{1}{12}$ inch wide.

186. Glass staining does not, by any means, consist in the mere application of coloring material to the surface of the glass, by methods similar to those employed in oil painting. The colors used are of a peculiar kind, possessing the power of vitrifying at a high temperature and fixing themselves unalterably on the glass. After the paint has been applied, the glass must be exposed to a certain heat in a furnace adapted to this purpose, the application of the vitrifiable colors being also duly attended to. Take, for example, an ecclesiastical window. It always consists of a great number of pieces of colored glass whose various hues illuminate an ornamental pattern based on a historical or religious subject. These pieces of glass are either symmetrical or irregular, agreeing with the sentiment of the composition itself. Arranged in their proper places, they are encased in lead and united to form one complete piece. The pieces are, in turn, united by an iron framework called the *arming*.

187. In the successful application of this work, the science of the chemist and the skill of the glazier are invoked to assist the painter. The pigments vary in hardness according to their composition, and must always be sufficiently hard to resist the friction of solid, firm bodies with which they may come into contact; but since the surfaces of stained-glass windows are little exposed to causes harmful to the pigment, the artist is not always to exclude those pigments endowed with moderate hardness only. The

pigments must offer such resistance to the chemical action of outside influences as not to be affected by air, water, sulphureted hydrogen, or other atmospheric gases. But whether or not the pigments are acted upon by bodies with which they accidentally come into contact, expansibility is the principal quality which they must, in precise and accurate degree, possess. The expansibility of the pigment must, in the frequent changes of temperature undergone by the painted plates of glass, during and after burning, be in exact proportion to that of the glass; for, lack of this proportion must, by producing movements in the glass in opposite directions, occasion many fractures. Pigments in this respect ill suited to the glass, split and peel off the vitreous surface, but the glass, on account of its thickness and firmness, remains uninjured.

188. Mosaic Glass Painting.—Much that has been already said may apply to the forcing of designs with colored pieces of pot metal, or, in part of these, and in part of painted white glass. Mosaic glass painting requires two cartoons; one, finished and colored, is used by the artist as a pattern, serving to determine the arrangement of the pieces of glass according to their several colors, and the manner of introducing the leaden ribs to fasten these pieces together. Each piece of glass to be introduced into the pattern must be distinguished by a separate number. The other cartoon bears only the dark outlines of the lead painting, the several parts numbered to correspond with the first, and is to be cut in pieces according to the outlines, each piece diminished in size all around by one-half the thickness of the leaden bar of the jointing, so that the pieces of glass may be cut with exactitude to their proper dimensions. The glass may be cut either with a diamond or by tracing the line of division with a red-hot iron.

189. Fig. 80 is a modern design for a stained-glass window as it appears when received from the designer. The lines on which the glass must be cut to fit it together in the leading, do not appear on the original drawing, or

Fig. 80.

cartoon, as it is called, but are marked out later and cut. Each piece is then separately painted by the artist, using the cartoon as a guide, and all are then baked, or fired, in the muffle, in order to vitrify the colors and fix them in the surface of the glass. The pieces are then fitted together, secured with the lead strips, and the complete design framed in a sash, or other support, to preserve it until it is required to place it in its final support, the window. Iron rods are sometimes secured to the leading by means of small pieces of copper wire soldered to the leads at regular intervals. These rods are spaced from 2 to 6 inches apart and tend to keep the finished design from bending in any of the joints or breaking across the small pieces of glass. They are left in place after the window is set, and should, therefore, be so placed as not to cast a shadow across the design when the window is between the observer and the source of light.

190. Glass painters had already, in the fourteenth century, begun to copy nature with some success. Light and shade then became more vigorous, and the flesh, instead of being represented, as in older specimens, by violet-tinted glass, is painted in white glass with a reddish-gray color. The pieces of glass are larger, the strips of lead placed at wider intervals; large single figures, sometimes occupying a whole window, are placed under elaborate Gothic canopies, and on a plain blue or red instead of mosaic ground. The tendency of the artist to produce work in individual form is, from the beginning of the fourteenth century, more and more observable. The decorations, which, like frames, surround the figures and the subjects, always borrowed from the architecture of the times, are, from day to day, increased, presenting a great variety of ornamental lines, often with pleasing and impressive effect.

During the greater part of the fifteenth century, a parchment roll with a verse of scripture sets forth the subject of the decoration. Blue and red hangings, introduced behind the figure, are of damasked stuffs of great richness. Borders are rare, but when found, consist of branches meager in

foliage, painted upon strips of glass. In the second half of the fifteenth century, buildings and landscape in perspective are first brought in, while in the sixteenth century, the artist skilfully renders graceful compositions, with depth of background, trees, fruits, and flowers.

Painting Gothic borders on the mosaic was, at first, limited almost exclusively to the symmetrical arrangement of pieces of glass of various colors. As the taste for correct drawing developed, the simple arrangement of glass lost its importance and was finally eclipsed by painting. In the sixteenth and seventeenth centuries, correct delineation in painted windows became the rule, the result being a much higher and more elaborate rendition of historical designs. Since that time, a reaction has, from one extreme to another, taken place. We see, at one time, the ground diversified with a multitude of brilliant colors, variegated by figures, after patterns more or less clearly defined, while, at another, these figures, surrounded by splendid borders or friezes, are obliged to give way to architectural backgrounds and imitations of the antique.

191. The **easel** for glass painting consists of an oblong wooden frame, whose greatest dimension is its height, its interior border supplied with grooves for the reception of a plate of glass. This frame, placed within a still larger one, may be raised or lowered in grooves at pleasure. The exterior frame has, on both sides of its length, a series of holes, and the interior frame may be thus supported at any given height, by means of pegs inserted into these holes. The easel is usually placed obliquely on a raised form or table, supported in this position by two props at the back, bound together with a cross-bar, hinged at the top and held at a proper distance by movable hooks, permitting it to be closed up at pleasure.

192. The wax for fastening the plates of glass on the easel is similar to modeling wax, and consists of beeswax, 4 parts, Burgundy pitch, 1 part. To the Burgundy pitch it owes its ductility, while it derives its adhesiveness from the greasy matter nearly always contained in the beeswax of commerce.

193. The glazier's work consists: First, in cutting out the various pieces of glass to be stained or painted, and giving these the exact form required by the outlines of the cartoon; second, in encasing the glass in lead when the painting is finished, and forming it into the panels of which the whole picture is composed; third, in arranging it permanently in the arming.

194. Cutting the Glass.—The cartoon having been placed upon a table, the glazier lays upon it a sheet of glass whose color is decided by the artist and by him outlined in white or some other color. The glazier then cuts it with a diamond, taking care, among other things, to leave a space between each piece of glass, determined by the thickness of the interior of those strips of lead by whose edges the pieces of glass are afterwards united.

195. Leading.—The strips of lead, a section of one of which is shown in Fig. 81, consist of two narrow ribbons joined together lengthwise, by a narrow strip of the same metal, running along the center. The cartoon, according to which the pieces of glass have been cut out, is also used for putting these pieces together and leading them. Beginning as nearly as possible in the center of the picture, the glazier works outwards from the center in each direction. When the first piece to be fixed has been laid in position, it is fastened in several places by pegs driven into the table. These pegs, or nails without heads, fulfil this purpose by aid of small pieces of milled lead, laid between the pegs and the glass. One of the sides of the glass is then enclosed in a piece of lead. When this strip of lead has followed the whole outline of the glass, pressure being, at the same time, applied, the superfluous breadth is cut off with a lead knife. A second piece of glass, placed like the first with pegs until the strip of lead is fixed on, is then put in place. The edges of the lead are then pressed down, and this operation continued until the panel is finished.

FIG. 81.

196. Glass embossing is a description of ornamental

glass having nothing in common with the art of glass painting, but frequently and advantageously employed as an auxiliary to stained-glass decoration. Generally used for **overlaid glass,** that is, white glass upon which a coating of color has been flashed in the blowing, it consists of a kind of white drawing upon a colored ground, obtained by removing the coating of colored glass where, according to the drawing, it is intended to lay bare the white stratum. The process of engraving requires that the glass be first covered with a coating of linseed oil boiled with litharge, to preserve from the action of the acids those parts not to be acted upon. This layer is then dried in the drying oven, and the varnish removed by means of a *graver* or *needle* and a scraping instrument from those parts where the glass is to be acted upon by the acid. The plate of glass is next laid horizontally on a table and a raised border of wax carried around the edges of the glass, upon which the acid is then poured. The acid is allowed to remain on the glass as long as it may be required to destroy the colored stratum wherever exposed. This operation completed, the glass is washed and freed from the borders of wax and the wax ground. The cleanliness and firmness of the engraving are then in proportion to the thinness of the coating and the diluted

FIG. 82.

state of the acid. If very much concentrated, the action of the acid extends over the etching ground and seems to undermine the lines.

Fig. 82 presents a door panel of white glass flashed with any one color, which may be vitrified or eaten away by the aid of hydrofluoric acid until it shows the base or white surface only, thus rendering a beautiful effect, rich in appearance and clear in definition.

Fig. 83 represents a similar panel, with a design from nature, and may, like the preceding, be worked on white, blue, or orange glass. This design may also be embossed on simple white glass by drawing an exact outline of the size required. Placing this underneath the sheet of plate glass, take a sable pencil and paint in the background carefully with Brunswick black and turpentine, accurately tracing the lines of the design and keeping the glass rigidly free from grease or grease spots. When this glass is ready to receive the acid, fix the wax around the edges and pour the dilute hydrofluoric acid quickly over the surface, allowing it to remain until the design required is sufficiently etched. Then pour off the acid, wash the plate freely and remove the wax. This wax is composed of three parts beeswax and one part Burgundy pitch, fused together and forming a soft putty, resisting any acid.

FIG. 83.

ESTIMATING AND CALCULATING QUANTITIES.

INTRODUCTION.

1. Scope of Subject.—The art of estimating is very important both to the architect and to the builder; to the latter, in that he must employ some systematic method of estimating in order to carry on his business successfully, and to the former for the reason that he should at all times be able to estimate the cost of the buildings which he designs.

The science—for such it is—of fixing prices on a piece of work in any branch of the building trades, must be based on an extended experience. Any one can, with a little practice, learn to take off the quantities of materials, but when it comes to determining the rates, only a person of large and varied knowledge of building and costs of various details can accurately estimate the time and labor required to complete the work. It is the aim of this section to put the student on the proper course to pursue in order to become a practical estimator. For this purpose, a number of detailed estimates, and a complete example in estimating, are given as guides; it should be remembered, however, that as the prices of materials and labor vary from those assumed, so will the estimates vary. The estimates given herein are, in general, net figures, and do not include any contractor's profit.

2. Qualifications of the Estimator.—In this country there are no standard or definite rules on estimating which

hold good in every section, the builders of each locality having their own ideas and customs in regard to the subject; this fact, together with the difference in the cost of labor in various parts of the country and the fluctuations in the market price of materials, requires, as before remarked, that the really clever estimator be a man of long and varied experience in the business. There are, however, certain practical rules and suggestions that will materially assist in taking off the quantities, and in valuing the labor required for any building operation. These will be taken up and considered in detail in this section.

3. Important Factors.—The prime considerations in making an estimate are time and accuracy; to these ends, the estimator must systematize his efforts and endeavor to do a maximum amount of work in a minimum amount of time; but not at the expense of accuracy, which is the most important factor, and which is only insured when the figures are carefully checked. The estimator should, therefore, while avoiding too great refinements in calculation, aim at correctness rather than speed in doing the work. Very frequently do the effects of haste and inaccuracy in estimating the cost of a structure become evident when it is too late to remedy the errors, resulting sometimes in the financial ruin of the builder who trusts too implicitly in the estimator's figures.

A record should be kept of all estimates made, as this kind of information is most valuable, and establishes a precedent upon which to base subsequent estimates, as well as a check on the work at hand.

PRINCIPLES OF ESTIMATING.

OUTLINE OF THE WORK.

4. Schedule.—The drawings and specifications for a structure are the guides which the estimator must follow in making his computations. All measurements necessary for calculating the quantity of the materials required are obtained from the drawings; and all information in regard to the

character of the workmanship and the quality of materials to be used is furnished by the specifications.

In compiling a schedule, there are three stages to the operation: *first*, taking the dimensions for each of the various classes of work; *second*, computing and collecting the quantities; and *third*, estimating the cost. In carrying out the first of these steps, each of its subdivisions should be considered in the order in which the work will be executed in the building; this order is about as follows:

1. Excavation.	5. Roofing.	9. Heating and Ventilation.
2. Stonework.	6. Plastering.	10. Plumbing and Gas-Fitting.
3. Brickwork.	7. Joinery.	11. Painting and Papering.
4. Carpentry.	8. Hardware and Ironwork.	12. Glazing.

The third step, estimating the cost, may be subdivided into cost of labor and cost of material. The latter can be definitely fixed by an examination of lists giving current prices of materials; while the former must be based on a fixed rate of wages per day for the various classes of workmen.

The second and third branches of the work, being closely connected with the first, will be partially considered in connection with it, and, later, in detail in the complete example on estimating.

APPROXIMATE ESTIMATING.

5. Preliminary Estimate.—In order to make a preliminary estimate, before the plans of a structure are drawn, but after the general dimensions of the proposed building have been determined, architects and builders sometimes employ a method of approximate estimating, by which the cost is figured at so much per cubic foot of the building, the

rate varying according to its character and the finish required. The method is also considerably used by insurance companies in fixing the amount to be placed on a building. It must be borne in mind by the student that this method gives the approximate cost only, and should never be used in figuring the contract price of a building. This estimate, however, may be used to advantage in checking the accurate estimate, with which it will frequently be found to agree remarkably well.

The following table shows the approximate cost per cubic foot of various kinds of structures. In computing the contents of a building, there is no uniformity in practice, but no great error will be made in figuring the solid contents from floor of cellar to ridge of roof.

COST OF BUILDINGS PER CUBIC FOOT.

Class of Building.	Cost. Cents per Cubic Foot.
Small frame buildings, costing from $800 to $1,500	8 to 9
Frame houses, 8 to 12 rooms, costing from $1,500 to $10,000	9 to 11
Brick houses, 8 to 10 rooms	10 to 14
Highly finished city dwellings (brick or stone)	17 to 20
Schoolhouses (brick)	9 to 11
Churches (stone)	20 to 25
Office buildings (well finished)	30 to 40
Hospitals, libraries, and hotels	32 to 44

ESTIMATING SCHEDULE.

6. Accurate Estimate.—There are so many items to be considered in a careful estimate, that the estimator should have a list of those coming under each of the main headings

enumerated in the preceding paragraphs, and in compiling a schedule he should follow this order. The subjoined list, which is arranged to assist in making an estimate on a dwelling house, will serve as an example of the general method which should be adopted.

EXCAVATION.

Cellar	Catch basins
Areas	Pipe trenches
Piers	Grading
Privy vaults	Filling
Footings	Labor
Cesspool	

STONEWORK.

Lime	Area walls
Cement	Chimneys
Sand	Footings
Mortar	Cut or dressed stonework
Concrete	Carved stonework
Foundation walls	Anchors and bolts
Partition walls	Labor
Piers	

BRICKWORK.

Lime	Cesspools
Cement	Range setting
Sand	Furnace setting
Mortar	Footings
Foundation walls	Chimneys
Exterior walls	Trimmer arches
Partition walls	Brick hearths
Area walls	Labor

CARPENTRY.

Framing.

Girders in cellar	Headers
Sills	Trimmers
Cross-sills	Common rafters
Posts	Hip rafters
Beams	Valley rafters
Girts	Purlins
Studs	Furring
Plates	Ridge pole
Deck plates	Collar beams
Tower plates	Lintels
Braces	Framing piers
Joists, basement	Outlookers
Joists, first story	Carrying beams
Joists, second story	Ironwork
Joists, third story	Rods and bolts
Joists, attic story	Nails and spikes
Ceiling beams	Labor

Covering.

Sheathing lumber	Flooring
Sheathing paper	Corner boards
Base	Casings
Siding	Cornice
Shingles	Labor

ROOFING.

Tin	Flashings
Shingle	Gutter linings
Slate	Solder
Tile	Cresting
Paper or felt	Finials

Roofing—*Continued.*

Painting tin	Conductor hooks and fastenings, nails and hooks
Hanging gutters	Cast shoes or boots
Conductor pipes	Labor
Conductor heads	

PLASTERING.

Lath	One-coat work
Lime	Two-coat work
Sand	Three-coat work
Hair	Stucco cornices
Plaster of Paris	Stucco arches
Plastering mortar	Stucco centers
Deafening	Nails
Back plastering	Labor

JOINERY.

Inside and Outside Finish.

Window frames	Wainscoting
Door frames	Moldings
Sashes	Planed lumber
Doors	Posts
Base	Columns
Architraves	Balusters
Corner and plinth blocks	Hand railing
Outside and inside blinds	Nails and screws
Brackets	Labor

Stairs.

Rough lumber	Hand railing
Treads and risers	Balusters
Strings	Brackets
Spandrels	Bolts
Moldings	Nails and screws
Newels	Labor

HARDWARE.

Mortise locks
Rim locks
Padlocks
Butts (various sizes)
Wrought butts
Strap hinges
Blind hinges
Sash fasteners
Sash weights
Shutter bars
Sash lifts
Sash cord
Transom lifters
Cupboard catches
Hooks and eyes
Drawer pulls
Mortise bolts
Door stops
Door hangers
Axle pulleys

HEATING AND VENTILATING SYSTEM.

Hot-Air Heating.

Furnace
Cold-air ducts and slide dampers
Hot-air pipes, elbows, and dampers
Register boxes
Registers
Sheet-tin and asbestos fire protection
Smoke pipe
Labor

Steam Heating.

Boiler
Regulating and safety appliances
Smoke pipe
Steam pipes
Return pipes
Fittings
Hangers
Indirect, direct-indirect, and direct radiators
Radiator valves
Air vents
Floor and ceiling plates
Galvanized sheet-iron casings for indirect stacks
Sheet-iron indirect flues, screens, and dampers
Indirect registers and boxes
Japanning and bronzing
Pipe coverings
Labor

Hot-Water Heating.

Heater
Automatic damper regulator
Smoke pipe
Expansion tanks
Radiators, pipes, fittings, etc., same as for steam heating
Labor

PLUMBING AND GAS-FITTING.

Plumbing Fixtures.

Kitchen range, with water-back
Plunge baths
Shower baths
Foot baths
Sitz baths
Wash basins
Water closets
Urinals
Kitchen sinks
Pantry sinks
Slop sinks
Laundry tubs
Safes
Hot and cold water faucets for fixtures
Labor

Water Supply.

City Supply.

Permits
Corporation connections
Excavation
Extra-heavy lead, iron, or brass service pipe
Curb cock and box
Stop and waste

Well Supply.

Storage cisterns
Cistern filters
Pumps
Supply tanks
Outside piping
Lawn and garden hydrants
Fittings, etc.
Wrought-iron pipe fittings
Brass-pipe fittings
Lead-pipe fittings
Solder nipples
Stop-cocks
Pipe straps
Metal tacks
Kitchen boiler and stand
Wiping solder
Labor

House Drainage.

Permits
Sewer connections
Excavation
Vitrified sewer pipe and fittings
Earthenware traps

House Drainage—*Continued.*

Portland cement
Unglazed drain pipe
Cast-iron soil pipe and fittings
Lead and oakum
Cast-iron traps
Handholes and cleanouts
Lead bends, brass ferrules
Lead soil, waste, and vent pipes
Lead traps
Brass traps
Fixture connections (brass)
Wrought-iron, galvanized, or asphalt-coated drain, soil, and vent pipes and fittings
Fresh-air inlets, vent caps
Vent-pipe flashings
Wall hooks, straps, bands, and hangers
Labor

Gas-Fitting.

Permit
Tapping main
Excavation
Meters
Stop-cocks
Drip cups
Piping
Straps and hangers
Fittings
Pressure regulators
Chandeliers
Pendants
Wall brackets
Pillar lights
Globes, shades, and fire guards
Gas stoves and ranges
Gas-heater connections
Labor

PAINTING AND PAPERING.

Painting.

Body of house
Trimmings
Blinds
Roof
Porches
Inside work
Floors
Ceilings
Walls
Sash
Shelving
Mantels
Oiling
Polishing
Varnishing
Fences
Outbuildings
Labor

Papering.

Paper	Lining paper
Borders	Labor

GLAZING.

Sheet glass (single or double thick)	Ribbed glass
	Frosted glass
Plate glass	Glazier's points
Leaded glass (stained or clear)	Putty
	Labor

EXCAVATION.

7. Matters To Be Considered.—Excavation is generally measured by the cubic yard, although, in a few localities, measurement by the perch is still in use. If the latter method is adopted, it should be stated just what is meant by a perch, as this varies considerably in different parts of the country.

Before fixing the price for excavation, it is advisable to investigate the character of the soil, by making boring tests. Where there is rock excavation which requires to be blasted, a special price should be given in the estimate. If the ground is wet, rendering pumping necessary, provision should be made for the cost of the extra labor needed. The disposition to be made of the excavated material should also be considered, as, if it must be hauled a long distance, the cost will be much greater than if the soil may be *wasted* near by. To aid in estimating the actual cost, it is convenient and approximately correct to consider 1 cubic yard of ordinary earth as a load for an ordinary two-horse wagon.

In making calculations of the amount of material to be removed, care must be taken to note the existing levels of the ground and those required by the drawings. The excavation should be figured (and made) at least 1 foot greater than the size of the foundation, so as to provide room for setting the masonry, pointing, etc.

Excavation for pipes, drains, etc. should be at least 9 inches wider than the diameter of the pipe to be laid therein. If the soil in which the excavation is made is of a

loose and sandy nature, likely to crumble and slide, a slope, say of 3 inches horizontal to 1 foot vertical, should be allowed on both sides of the trenches. If the latter are of considerable depth, it is sometimes necessary to curb or shore up the sides, in which case an allowance should be made in the estimate for the lumber required.

If piles are required, figure them at so much per lineal foot, driven.

CALCULATION OF EXCAVATION.

8. Volume.—The ordinary rules of mensuration are all that are needed to compute the volume of any excavation. The work is very simple when the area to be removed is

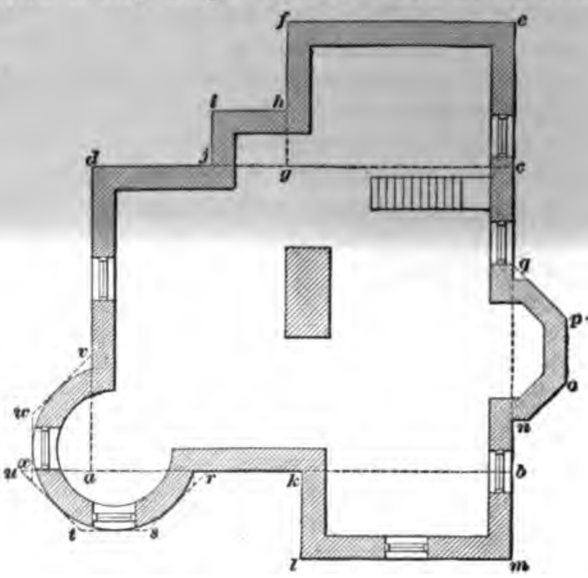


FIG. 1.

regular; but when the outlines are very irregular and broken, the easiest method to calculate the excavation is to divide the plan into geometrical figures which are easy to compute, and calculate the area of each one separately. These areas being added, and their sum multiplied by the depth of the cellar, will give the volume of the excavation.

An illustration of this method is shown in Fig. 1, which represents the plan of an irregular foundation. To compute the area of the excavation, the plan is divided into the rectangles *a d c b*, *l k b m*, *j i h g*, *g f e c*, and the polygons *n q p o*, *t u r s*, and *a x w v*. By scaling on the drawing the dimensions of these figures, the area of each may then be readily determined by calculation.

It is sometimes required to find the volume of an excavation, the surface of which is very irregular, as in Fig. 2; in

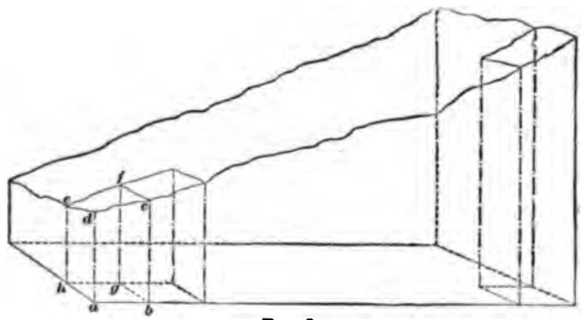


FIG. 2.

such a case the following method may be used: Divide the surface of the excavation into a number of squares or rectangles, as at *d e f c*; these represent the ends of prisms, the other ends of which are the bottom of the excavation, as at *a h g b*. Then calculate the volume of each prism by ascertaining the height of the four corners above the bottom; add these measurements together, divide the sum by 4 (the number of corners), and multiply the result by the end area, as *a h g b*; the product will be the volume of the prism. The sum of these partial volumes will be an accurate estimate of the contents of the excavation.

MASONRY.

9. Stone Masonry.—This is generally measured by the perch; in some sections of the country, however, measurement by the cord is preferred, but the best method (as being invariable) is by the cubic yard. In estimating by the perch, it should be stated how much the perch is taken at, whether

24⅞ or 25 cubic feet. Note should also be made in regard to corners and deduction for openings; in most localities it is not customary to deduct openings under a certain size, and corners are usually measured twice.

Rough stone from the quarry is generally sold under two classifications; namely, rubble and dimension stone. *Rubble* consists of pieces of irregular size, such as are most easily obtained from the quarry, up to 12 inches in thickness by 24 inches in length. Stone ordered of a certain size, or to square over 24 inches each way and to be of a particular thickness, is called *dimension stone.*

Rubble masonry and stone backing are generally figured by the perch or cubic yard. Dimension-stone footings are measured by the square foot unless they are built of large irregular stone, in which case they are measured the same as rubble. Ashlar work is always figured by the superficial foot; openings are usually deducted, and the jambs are measured in with the face work. Flagging and slabs of all kinds, such as hearths, treads for steps, etc., are measured by the square foot; sills, lintels, molding, belt courses, and cornices, by the lineal foot, and irregular pieces are generally figured by the cubic foot. All carved work is done at an agreed price by the piece.

DATA ON RUBBLE MASONRY.

10. The following proportions and cost of materials, and amount of labor required to lay 1 perch of rubble masonry, are reasonably accurate, and will serve to give an idea of how to estimate such work.

COST OF RUBBLE MASONRY.

Using 1-to-3 Lime Mortar.

1 perch stone (25 cubic feet) delivered at work	$1.25
1 bushel lime	.25
$\frac{1}{6}$ load of sand, at $1.50 per load	.25
$\frac{1}{3}$ day mason's labor, at $2.50 per day	.83
$\frac{1}{4}$ day helper's labor, at $1.50 per day	.38
Total cost	$2.96

Using 1-to-3 Portland Cement Mortar.

1 perch stone	$1.25
$\frac{1}{2}$ barrel Portland cement, at $2.60 per barrel	1.30
$\frac{1}{6}$ load sand, at $1.50 per load	.25
$\frac{1}{3}$ day mason's labor, at $2.50 per day	.83
$\frac{1}{4}$ day helper's labor, at $1.50 per day	.38
Total cost	$4.01

Using 1-to-3 Rosendale Cement Mortar.

1 perch stone	$1.25
$\frac{1}{2}$ barrel Rosendale cement, at $1.25 per barrel	.63
$\frac{1}{6}$ load sand, at $1.50 per load	.25
$\frac{1}{3}$ day mason's labor, at $2.50 per day	.83
$\frac{1}{4}$ day helper's labor, at $1.50 per day	.38
Total cost	$3.34

DATA ON ASHLAR AND CUT STONE.

11. Cost.—The following figures are average prices of stone when the transportation charges are not excessive, and are not given as fixed values, but more to show the relative costs. They are based on quarrymen's wages of $2.25 per day, and stone-cutters' wages of $3.00 per day.

First-class rock-face bluestone ashlar, with from 6 to 10 inch beds, dressed about 3 inches from face, will cost, ready for laying, from 25 to 40 cents per square foot, face measure; while very good work will cost from 35 to 45 cents per square foot. Regular course bluestone ashlar, 12 to 18 inches high, with from 8 to 12 inch beds, will cost about 50 cents per square foot. To this (and the previous figures) must be added the cost of hauling, which, on an average, will be about 2 cents per square foot. The cost of setting ashlar may be taken at about 10 cents per square foot.

The rough stock for dimension stone will cost, at the quarry, if Quincy granite, in pieces of a cubic yard or less, from 50 cents to 75 cents per cubic foot; if bluestone, about 50 cents; if Ohio sandstone, about 30 cents per cubic foot; if Indiana limestone, about 25 cents per cubic foot; and if Lake Superior redstone, about 40 cents per cubic foot.

Flagstones for sidewalks, ordinary stock, natural surface, 3 inches thick, with joints pitched to line, in lengths (along walk) from 3 to 5 feet, will cost, for 3-foot walk, about 8 cents per square foot (if 2 inches thick, 6 cents); for 4-foot walk, 9 cents; and for 5-foot walk, 10 cents per square foot. The cost of laying all sizes will average about 3 cents per square foot. The above figures do not include cost of hauling.

Curbing, 4″×24″, granite, will cost, at quarry, from 25 to 30 cents per lineal foot; digging and setting will cost from 10 to 12 cents additional; and the cost of freight and hauling must also be added.

The following figures show the approximate cost of cut bluestone for various uses:

Flagstone, 5-inch, size 8′×10′, edges and top bush hammered, per sq. ft., face measure	$0.65
Flagstone, 4-inch, size 5′×5′, select stock, edges clean cut, natural top, per sq. ft.	.30
Door sills, 8″×12″, clean cut, per lin. ft.	1.25
Window sills, 5″×12″, clean cut, per lin. ft.	.80
Window sills, 4″×8″, clean cut, per lin. ft.	.45
Window sills, 5″×8″, clean cut, per lin. ft.	.60
Lintels, 4″×10″, clean cut, per lin. ft.	.60
Lintels, 8″×12″, clean cut, per lin. ft.	1.10
Steps, sawed stock, 7″×14″, per lin. ft.	.90
Water-table, 8″×12″, clean cut, per lin. ft.	1.25
Coping, 4″×21″, clean cut, per lin. ft.	1.10
Coping, 4″×21″, rock-face edges and top, per lin. ft.	.45
Coping, 3″×15″, rock-face edges and top, per lin. ft.	.25
Coping, 3″×18″, rock-face edges and top, per lin. ft.	.30
Platform, 6″ thick, per sq. ft.	.45

To the prices of cut stone above given, must be added the cost of setting, which for water-tables, steps, etc. will be about 10 cents per lineal foot; and for window sills, etc., about 5 cents per lineal foot. In addition, allow about 10 cents per cubic foot for fitting, and about 5 cents per cubic foot for trimming the joints after the pieces are set in place.

12. Day's Work.—A stone cutter can cut about 6 square feet of granite per day, 8 square feet of bluestone, and about 10 square feet of Ohio sandstone or limestone. These figures are for 8-cut patent-hammered work. For rock-face ashlar (beds worked about 3 inches from face, the rest pitched), a workman can dress from 25 to 28 square feet per day, of random ashlar; and from 18 to 20 square feet of coursed ashlar. In dressing laminated stone, from two to three times more work can be done in a day on the natural surface than on the edge of layers. In figuring cut stone, an ample allowance should be made for waste, which, on an average, will be 25 per cent.

BRICKWORK.

13. Brickwork is generally estimated by the thousand bricks laid in the wall, but measurements by the cubic yard and the perch are also used. The following data will be useful in calculating the number of brick in a wall. For each superficial foot of wall 4 inches (the width of one brick) in thickness, allow $7\frac{1}{2}$ bricks; for a 9-inch (the width of two bricks) wall, count 15 bricks; for a 13-inch (the width of three bricks) wall, allow $22\frac{1}{2}$ bricks; and so on, estimating $7\frac{1}{2}$ bricks for each additional 4 inches in thickness of the wall. The above figures are for the ordinary eastern standard brick, which is about $8\frac{1}{4}$ in. $\times$ 4 in. $\times 2\frac{1}{4}$ in. If smaller brick is used, the figures will be increased proportionately. If brickwork is estimated by the cubic yard, allow 500 brick to a yard. This figure is based on the use of brick of the size above given, and mortar joints not over $\frac{3}{8}$ inch thick. If the joints are $\frac{1}{8}$ inch thick, as in face brickwork, 1 cubic yard will require about 575 bricks. In making calculations of the number of bricks required, an allowance of, say, 5 per cent. should be made for waste in breakage, etc.

The practice in regard to deductions for openings is not uniform throughout the country, but usually small openings are counted solid, as the cost of the extra labor and the waste in working around these places balances that of the

brickwork saved. All large openings, 100 square feet or over in area, should be deducted.

When openings are measured solid, it is not usual to allow extra compensation for arches, pilasters, corbels, etc. Rubbed and ornamental brickwork should be measured separately, and charged for at a special rate.

Brick footings may be computed by the lineal foot. The following table, based on steps or offsets of one-quarter brick, or 2 inches, for each course in the footing, gives the number of bricks per lineal foot in footings for brick walls from 9 to 26 inches thick:

9-inch wall................	10½ bricks per lin. ft.
13-inch wall................	22½ bricks per lin. ft.
18-inch wall................	39 bricks per lin. ft.
22-inch wall................	60 bricks per lin. ft.
26-inch wall................	85½ bricks per lin. ft.

DATA ON BRICKWORK.

14. The following estimates on the cost of brickwork are very carefully compiled, and will be found trustworthy. It is to be understood that the prices will vary with the cost of materials and labor; but the proportions will be constant. The figures are based on *kiln*, or actual, count—that is, with deductions for openings. When the work is measured with no deductions for openings, the cost per thousand may be assumed as about 15 per cent. less than the prices given, which are exclusive of builder's profit.

COST OF COMMON BRICKWORK PER THOUSAND BRICK.

Using 1-to-3 Lime Mortar.

1,000 brick....................................	$6.00
3 bu. lime, at 25 cents per bu....................	.75
½ load sand (10 bbl. to load), at $1.50 per load......	.75
Bricklayer, 7 hours, at 35 cents per hour...........	2.45
Laborer, 7 hours, at 15 cents per hour.............	1.05
Total....................................	$11.00

Using 1-to-3 Portland Cement Mortar.

1,000 brick	$6.00
1½ bbl. Portland cement, at $2.60 per bbl	3.90
½ load sand	.75
Bricklayer, 7 hours, at 35 cents per hour	2.45
Laborer, 7 hours, at 15 cents per hour	1.05
Total	$14.15

Using 1-to-4 Lime-and-Cement Mortar.

1,000 brick	$6.00
3 bu. lime, at 25 cents per bu	.75
½ load sand	.75
1 bbl. cement	2.60
Bricklayer, 7 hours, at 35 cents per hour	2.45
Laborer, 7 hours, at 15 cents per hour	1.05
Total	$13.60

Using 1-to-3 Rosendale Cement Mortar.

1,000 brick	$6.00
1½ bbl. Rosendale cement, at $1.25 per bbl	1.87
½ load sand	.75
Bricklayer, 7 hours, at 35 cents per hour	2.45
Laborer, 7 hours, at 15 cents per hour	1.05
Total	$12.12

COST OF PRESSED BRICKWORK PER THOUSAND BRICK.

Using Lime-Putty Mortar.

1,000 pressed brick, cost from $20 to $40 (average)	$30.00
1½ bu. lime	.38
¼ load fine sand	.37
Bricklayer, 30 hours, at 40 cents per hour	12.00
Laborer, 15 hours, at 15 cents per hour	2.25
Total	$45.00

CARPENTRY.

15. Carpentry should include general framing, roofs, floor joists, partitions, sheathing, flooring, furring, and plastering grounds.

16. Board Measure.—The rough lumber used in framing is measured by the board foot, which means a piece 12 inches square and 1 inch thick. Lumber is always sold on a basis of a thousand feet board measure; the customary abbreviation for the latter term is B. M.; that for thousand is M; thus, 500 feet board measure, costing $14.00 per thousand, would be written: 500 ft. B. M., at $14.00 per M.

To obtain the number of board feet in any piece of timber, the length of the scantling in inches is multiplied by the end area in inches, and the result is divided by 144. For example, the number of feet B. M. in a floor joist, 20 feet long, 3 inches thick, and 10 inches deep, will be: 240 in. (= 20 ft. × 12) multiplied by 30 sq. in. (the end area), and the product divided by 144, giving 50 feet B. M.

The following rule is that used by most contractors and lumber dealers: *Multiply the length in feet by the thickness and width in inches, and divide the product by 12.* Thus, a scantling 26 feet long, 2 inches thick, and 6 inches wide contains $\frac{26 \times 2 \times 6}{12} = 26$ feet B. M.

This rule, expressed in a slightly different manner, is more convenient for mental computation: *Divide the product of the width and thickness in inches by 12, and multiply the quotient by the length in feet.* Thus, a 2″ × 10″ plank, 18 feet long, contains $\frac{2 \times 10}{12} \times 18 = 30$ feet B. M.

17. Studs.—To calculate the number of studs—set on 16-inch centers—the following rule may be used: *From the*

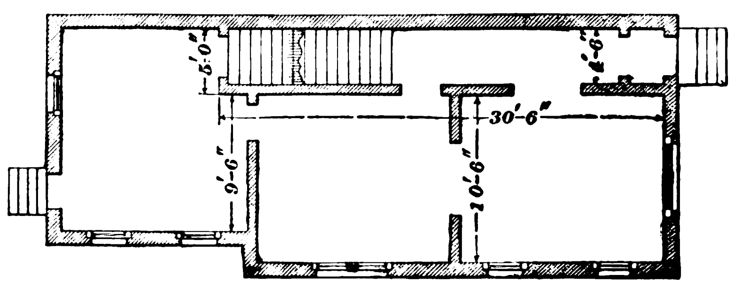


FIG. 3.

length of the partition deduct one-fourth, and to this result add 1. Count the number of returns, or corners, on the plan, and add 2 studs for each return. (The reason for adding 1 is to include the stud at the end, which would otherwise be omitted.) The *sills*, *plates*, and *double studs* must be measured separately.

For example, the number of studs required for partitions shown on the plan, Fig. 3, is computed as follows: The lengths are:

30 ft. 6 in.	
10 ft. 6 in.	
9 ft. 6 in.	
5 ft. 0 in.	
4 ft. 6 in.	
60 ft. 0 in.	

Deducting one-quarter from 60 feet, the remainder is 45 feet; adding 1 stud, the result is 46 feet. As there are 4 returns, with 2 studs for each, the total number is $46 + (4 \times 2) = 54$ studs.

As a general rule, when (as is usual) the studs are set at *16-inch* centers, *1 stud for each foot* in length of partition will be a sufficient allowance to include sills, plates, and double studs. Thus, if the total length of partitions is 75 feet, 75 studs will be sufficient for sills, double studs, etc. If the studs are set at *12-inch* centers, the number required will be equal to the *number of feet in length of partition plus one-fourth.* Thus, if the length of partitions is 72 feet, $72 + 18$, or 90, studs will include those required for sills, plates, etc.

The same rules may be used for calculating the number of joists, rafters, tie-beams, etc.

A good way to estimate bridging is to allow 2 cents apiece, or 4 cents per pair; this will be sufficient to furnish and set a pair made of $2'' \times 3''$ spruce or hemlock stuff.

18. Sheathing.—To calculate sheathing or rough flooring (which is not matched), find the number of feet B. M. required to cover the surface, making no deductions for door or window openings, for what is gained in openings is lost in waste. If the sheathing is laid horizontally, only the actual measurement is necessary; but if it is *laid diagonally, add 8 or 10 per cent.* to the actual area.

19. Flooring.—In estimating matched flooring, a square foot of $\frac{7}{8}$-inch stuff is considered to be 1 foot B. M. If the flooring is 3 inches or more in width, *add one-quarter* to the

actual number of board feet, to allow for waste of material in forming the tongue and groove; if less than 3 inches wide, *add one-third.* Flooring of 1⅛-inch finished thickness is considered to be 1¼ inches thick, and for calculating it the following rule may be used: *Increase the surface measure 50 per cent.* (This consists of 25 per cent. for extra thickness over 1 inch, and 25 per cent. for waste in tonguing and grooving.) To this amount add 5 per cent. for waste in handling and fitting.

In figuring the area of floors, openings for stairs, fireplaces, etc. should be deducted.

20. Weather boarding or **siding** is usually measured by the superficial foot. No deduction should be made for ordinary window or door openings, as these usually balance the waste in cutting and fitting. Careful attention must be given to the allowance for lap. If 6-inch, nominal width (actual width, 5⅝ inches), siding, laid with 1-inch lap, is used, *add one-quarter* to the actual area, in order to obtain the number of square feet of siding required. If 4-inch stuff is used, *add one-third* to the actual area. When, as above noted, no allowance is made for openings, the corner and baseboards need not be figured separately.

21. Cornices may be measured by the running foot, the molded and plain members being taken separately. A good method of figuring cornices is as follows: *Measure the girth, or outline, and allow 1 cent for each inch of girth, per lineal foot.* This price will pay for material and for setting, the cost of the mill work being estimated at 50 per cent.

22. Cost per Square Foot.—For all classes of materials which enter into the general framing and covering of a building, a close estimate may be made by analyzing the cost per square foot of surface; that is, the cost of labor and materials—studs and sheathing in walls, joists and flooring in floors, etc.—required for a definite area, should be closely determined, and this cost, divided by the area considered, will give the price per square foot. If the corresponding whole area is multiplied by the figure thus obtained, the

result will, of course, be the cost of that portion of the work. While it is usual to adopt a uniform rate for the various grades of work, a careful analysis will show that roof sheathing in place costs more than wall sheathing, owing to its position; and that the studs in walls and partitions cost more than floor joists, as they are lighter and require more handling.

The following example shows how to determine the cost per square foot of flooring, and indicates the general method to be pursued in like cases. The area used in the calculation is a square, or 100 square feet. The cost of labor is estimated at 50 per cent. of that of the materials, which experience has shown to be a very close approximation to the actual cost of general carpenter work.

COST OF FINISHED FLOOR PER SQUARE.

Joists, hemlock, 8 pieces, $3'' \times 10'' \times 10'$, 200 ft. B. M., at $14 per M	$2.80
Bridging, hemlock, 7 sets, $2'' \times 3'' \times 1'\ 4''$, 9 ft. B. M., at $14 per M	.13
Rough flooring, hemlock, $\frac{7}{8}$ inch thick, laid diagonally, 100 ft. + 25 ft. + 10 ft., 135 ft. B. M., at $17 per M	2.29
Finished flooring, white pine, $\frac{7}{8}$ inch thick, 125 ft. B. M., at $22 per M	2.75
Nails, (about) 3 lb., at $1.80 per 100 lb.	.05
Labor, 50 per cent. of cost of materials	4.01
Total cost for 100 sq. ft.	$12.03

Cost per square foot, $12.03 ÷ 100 = 12 cents.

A similar method may be followed in estimating the cost of interior finish, paneling, doors, etc.

23. The quantity of material that a workman will put in place in a day is very uncertain, depending upon the skill of the artisan, his rapidity of working, and the ease or difficulty of the work, all somewhat modified by numerous accidental circumstances. The subjoined figures, while founded on information gained by many years of experience, are only

intended to give an idea of the relative quantities, and are not a standard to be adhered to in all cases. The estimates are based on a 9-hour day, and wages at $2.25 per day. If the hours or pay are less or greater, the results will be correspondingly diminished or increased. Unless otherwise noted, the figures represent the labor of two men working together.

QUANTITIES OF MATERIAL PUT IN PLACE PER DAY.

Class of Material.	No. of Feet B. M., or No.	Remarks.
Studding, 2″ × 4″, or 2″ × 6″	600–800	Wall or partition.
Rafters	500–600	
Floor joists, 2″ × 10″, or 3″ × 12″	1,500	
Sheathing, unmatched	1,000	Laid horizontally.
Sheathing, unmatched	800	Laid diagonally.
Sheathing, matched	800	Laid horizontally.
Sheathing, matched	600	Laid diagonally.
Sheathing, roof	1,000	Plain gable roof.
Sheathing, roof	500	Much cut up by hips, valleys, dormers, etc.
Siding	700	Includes fitting and setting corner boards, base, trim, and scaffolding.
Posts and beams over cellars	400–500	Includes scarfing and doweling.
Plaster grounds, lineal feet, per man	400	For base and wainscot, straightened in good shape.
Bridging, No. pairs per hour, per man	12	Includes cutting and setting.
False jambs around openings, per hour, per man	1	

COST OF MISCELLANEOUS ITEMS OF CARPENTRY.

Class of Work.	Cost.	Remarks.
Setting window frames in wood buildings..........	$0.30	Per sq. ft. (about 1 hour time).
Furring brick walls, 1″×2″ strips, 12-inch centers....	.02½	Per sq. ft. (includes labor, material, and nails).
Furring brick walls, 1″×2″ strips, 16-inch centers....	.01⅞	Per sq. ft.
Cutting holes and fitting plugs in brick walls, 12-inch centers.................	.02	Per sq. ft.
Cutting holes and fitting plugs in brick walls, 16-inch centers.................	.01¾	Per sq. ft.
Window frames in brickwork.	.50	Each (includes nails and bracing).
Door frames in brickwork....	.50	Each.
Window frames in stonework.	1.25	Each, for ordinary work.
Window frames in stonework.	2.00	Each, for very careful work.
Door frames in stonework....	2.00	Each, for very careful work.
Furnishing and setting trimmer-arch centers	1.25	Each.
Arch centers, 3½ ft. span, 8-in. reveal..................	1.00	Each (includes supports and wedges).

24. Nails.—To calculate the quantity of nails required in executing any portion of the work, the following table, based on the use of cut nails, will be found useful:

TABLE FOR ESTIMATING THE QUANTITY OF NAILS.

Material.	Lb. Required.	Kind of Nails.
1,000 shingles..................	5	4d.
1,000 laths......................	7	3d.
1,000 sq. ft. beveled siding.....	18	6d.
1,000 sq. ft. sheathing	20	8d.
1,000 sq. ft. sheathing	25	10d.
1,000 sq. ft. flooring............	30	8d.
1,000 sq. ft. flooring............	40	10d.
1,000 sq. ft. studding.........	15	10d.
	5	20d.
1,000 sq. ft. furring $1'' \times 2''$.....	10	10d.
1,000 sq. ft. $\frac{7}{8}''$ finished flooring.	20	8d. to 10d. finish.
1,000 sq. ft. $1\frac{1}{8}''$ finished flooring	30	10d. finish.

The following table gives the name, length, and number per pound of various sizes of nails:

SIZES AND WEIGHTS OF NAILS.

Name.	Length in Inches.	No. per Lb.
3d. fine..............	$1\frac{1}{16}$	588
3d. common	$1\frac{1}{16}$	488
4d. common	$1\frac{3}{8}$	336
5d. common	$1\frac{1}{2}$ to $1\frac{3}{4}$	216
6d. finish	2	204
6d. common	2	166
7d. common	$2\frac{1}{4}$	118
8d. finish	$2\frac{1}{2}$	102
8d. common	$2\frac{1}{2}$	94
10d. finish............	3	80
10d. common	$2\frac{3}{4}$	72
12d. common	$3\frac{1}{8}$	50
20d. common	$3\frac{3}{4}$	32
30d. common	$4\frac{1}{4}$	20
40d. common	$4\frac{3}{4}$	17
50d. common	5	14
60d. common	$5\frac{1}{2}$	10

ROOFING.

25. Kinds of Roof Covering.—The roof coverings most generally used are shingles, slate, tin, tile, and tarred paper and gravel (known as gravel roofing). While there are slight variations in the methods of measuring the different kinds, they are all based on the square of 100 square feet.

26. Shingles.—In measuring shingle roofing, it is necessary to know the exposed length of a shingle; this is found by deducting 3 inches—the usual cover over the head of the lowest shingle in the four overlapping courses—from the length; dividing the remainder by 3, the result will be the exposed length, and multiplying this by the average width of a shingle, the product will be the exposed area. Dividing 14,400, the number of square inches in a square, by the exposed area of 1 shingle, will give the number required to cover 100 square feet of roof. For example, it is required to compute the number of shingles 18 in. × 4 in. necessary to cover 100 square feet of roof. With a shingle of this length, the exposure will be $\frac{18-3}{3} = 5$ inches; then the exposed area of 1 shingle is 4 in. × 5 in., or 20 square inches, and 1 square requires $14,400 \div 20 = 720$ shingles.

An allowance should always be made for waste in estimating the number of shingles required.

The following table is arranged for shingles from 16 inches to 27 inches in length, 4 inches and 6 inches in width, and for various lengths of exposure:

TABLE FOR ESTIMATING SHINGLES.

Exposure to Weather.	No. of Sq. Ft. of Roof Covered by 1,000 Shingles.		No. of Shingles Required for 100 Sq. Ft. of Roof.	
	4 In. Wide.	6 In. Wide.	4 In. Wide.	6 In. Wide.
4 inches..........	111	167	900	600
5 inches..........	139	208	720	480
6 inches..........	167	250	600	400
7 inches..........	194	291	514	343
8 inches..........	222	333	450	300

Shingles are classed as *shaved* or *breasted*, and *sawed* shingles. The former vary from 18 to 30 inches in length, and are about $\frac{1}{2}$ inch thick at the butt and $\frac{1}{16}$ inch at the top; the latter are usually from 14 to 18 inches long, and of various thicknesses. In the case of 18-inch shingles, there are 5 shingles to $2\frac{1}{4}$ inches; that is, the thickness at the butt is $2\frac{1}{4} \div 5 = .45$ inch, or about $\frac{7}{16}$ inch; and at the top the thickness is $\frac{1}{16}$ inch.

Strictly first-class shingles are generally given a brand of "XXX," and those of a slightly poorer quality are termed No. 2; but in some sections of the country, the brand "A" is general; thus, "Choice A" or "Standard A" are practically equivalent to the "XXX" shingle.

Shaved shingles are usually packed in bundles of 500, or 2 bundles per thousand. Sawed shingles are made up into bundles of 250, and are sold on a basis of 4 inches width for each shingle. If the wider ones are ordered, the cost per thousand is correspondingly increased. For example, if one thousand 4-inch shingles were required to cover an area, and 6-inch ones were ordered, only two-thirds as many, or 667, would be needed and furnished, while the cost would be that of 1,000 standard-width shingles.

Shingles cost from \$3.00 to \$5.00 per thousand, according to material and grade. Dimension shingles—those cut to a uniform width—if of prime cedar, shaved, $\frac{1}{2}$ inch thick at the butt and $\frac{1}{16}$ inch at the top, will cost \$9.00 to \$10.00 per thousand, but such shingles are usually 6 inches wide and 24 inches long, so that a less number will be required per square than of ordinary shingles.

A fairly good workman will lay about 1,500 shingles per day of 9 hours, on straight, plain work; while in working around hips and valleys, the average will be about 1,000 per day.

27. Slating.—In measuring slating, the method of determining the number of slates required per square is similar to that given for shingling; but in slating, each course overlaps but two of the course below, instead of three, as in

shingling. The usual lap, or cover of the lowest course of slate by the uppermost of the three overlapping courses, is 3 inches; hence, to find the exposed length, deduct the lap from the length of the slate, and divide the remainder by 2. The exposed area is the width of the slate multiplied by this exposed length, and the number of slates required per square is found by dividing 14,400 by the exposed area of 1 slate. Thus, if $14'' \times 20''$ slate are to be used, the exposed length will be $\frac{20-3}{2} = 8\frac{1}{2}$ inches; the exposed area will be $14 \times 8\frac{1}{2} = 119$ square inches, and the number per square will be $14,400 \div 119 = 121$ slates.

The following rules should be observed in measuring slating: Eaves, hips, valleys, and cuttings against walls are measured extra, 1 foot wide by their whole length—the extra charge being made for waste of material and the increased labor required in cutting and fitting. Openings less than 3 square feet are not deducted, and all cuttings around them are measured extra. Extra charges are also made for borders, figures, and any change in color of the work, and for steeples, towers, and perpendicular surfaces.

The following table, based on 3 inches lap, gives the sizes of the American slates, and the number of pieces required per square:

NUMBER OF SLATES PER SQUARE.

Size. Inches.	Number of Pieces.	Size. Inches.	Number of Pieces.	Size. Inches.	Number of Pieces.
6×12	533	9×16	246	14×20	121
7×12	457	10×16	221	11×22	138
8×12	400	9×18	213	12×22	126
9×12	355	10×18	192	13×22	116
7×14	374	11×18	174	14×22	108
8×14	327	12×18	160	12×24	114
9×14	291	10×20	169	13×24	105
10×14	261	11×20	154	14×24	98
8×16	277	12×20	141	16×24	86

The cost of slating varies from 7 to 9 cents per square foot, depending on the class of work.

28. Tin Roofs.—In estimating tin (and also other metal) roofs, hips and valleys are measured extra their entire length by 1 foot in width, to compensate for increased labor and waste of material in cutting and laying. Gutters and conductor pipes and leaders are measured by the lineal foot, 1 foot extra being added for each angle. All flashings and crestings are measured by the lineal foot. For seams, addition is made to superficial area, depending on the kind of seam used, whether single lock, standing, or roll and cap. No deductions are made for openings (chimneys, skylights, ventilators, or dormer-windows), if less than 50 square feet in area; if between 50 and 100 square feet, one-half the area is deducted; if over 100 square feet, the whole opening is deducted. An extra charge is made for labor and waste of material to flash around such openings.

A box of roofing tin contains 112 sheets 14 in. × 20 in., and weighs from 110 to 145 pounds per box, according to whether it is IC or IX plate. The IC plate, which is the most used, weighs about 8 ounces per square foot, and the IX, about 10 ounces. As there are considerable variations in the weights of tin made by different manufacturers, a fair average will be obtained by estimating IC tin at 1 pound, and IX tin at $1\frac{1}{4}$ pounds per sheet. Double-size roofing tin can be had 20 in. × 28 in., weighing, if IC, 225 pounds per box. This size is the most economical, as by its use much material and labor are saved, on account of the less number of seams and ribs required.

A 14″ × 20″ sheet will cover about 235 square inches of surface, using standing joints; or a box will cover about 182 square feet. With a flat lock seam, a sheet will cover 255 square inches, allowing $\frac{3}{8}$ inch all around for joints; or a box will lay 198 square feet. These figures make no allowance for waste.

Two good workmen can put on, and paint outside, from 250 to 300 square feet of tin roofing per day of 8 hours.

Tin roofing will cost from 8 to 10 cents per square foot, depending on the quality of material and workmanship.

29. **Tile roofs** are constructed of so many styles of tile that no general rules of measurement can be given, and every piece of work must be estimated according to the particular kind of tile used and the number of sizes and patterns. Information on all these points are to be found in the catalogues of tile manufacturers.

30. In **gravel roofing** the cost per square depends upon the number of thicknesses of tarred felt and the quantity of pitch used per square.

ROOF MENSURATION.

31. While the ordinary principles of mensuration are all that are necessary to calculate any roof area, yet the modern house, with its numerous gables and irregular surfaces, introduces complications which render some further explanation of roof measurement desirable. The most common error made in figuring roofs—and which should be carefully guarded against—is that of using the apparent length of slopes, as shown by the plan or side elevations, instead of the true length, as obtained from the end elevations.

32. The area of a plain gable roof, as shown in end and side elevations in Fig. 4, is found by multiplying the length gj by the slope length bd, and further multiplying by 2, for

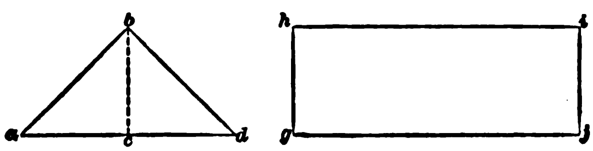


FIG. 4.

both sides. The area of the gable is found by multiplying the width of the gable ad by the altitude cb, and dividing by 2.

33. In Fig. 5 is shown the plan and elevation of a hip roof, having a deck *s*. The pitch of the roof being the same

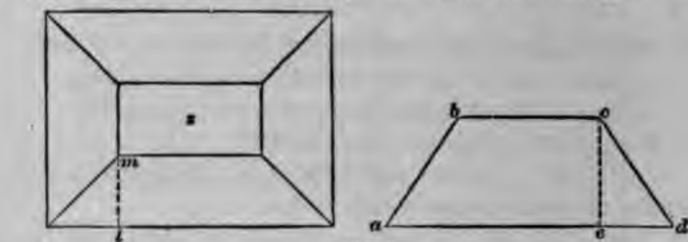


FIG. 5.

on each side, the line *c d* shows the true length of the common rafter *l m*. In Fig. 6 is shown the method of developing the true lengths of the hips, and the true size of one side of the roof. Let *a b c d* represent the same lines as the corresponding ones in Fig. 5. From the line *a d*, through *b* and *c*, draw perpendiculars, as *g h* and *e f*; lay off from *g* and *e* on these lines, the length of the common rafter *a b*, Fig. 5, and draw the lines *a h* and *d f*; then the figure *a h f d* will show the true shape and size of the roof shown in the elevation in Fig. 5. The area of the triangle *d e f* is equal to the area of the triangle *a g h* or a similar triangle *a i h*. Hence, the portion of the roof *a h f d* is equal in area to the rectangle *a i f e*, the length of which is half the sum of the eave and deck lengths, while its breadth is the length of a common rafter.

FIG. 6.

34. A method of obtaining the lengths of valley rafters, applicable also to hip rafters, is shown in Fig. 7, which is the plan of a hip-and-gable roof. To ascertain the length of the valley rafter *a b*, draw the line *a c* perpendicular to *a b*, and equal in length to the altitude of the gable; then

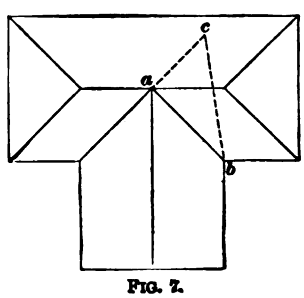


FIG. 7.

draw the line *c b*, which will be the true length of the valley rafter *a b*.

35. As an example of roof mensuration, the number of square feet of surface on the roof shown in Fig. 8 will be calculated.

The area of the triangular portion *a c b* is equal to the

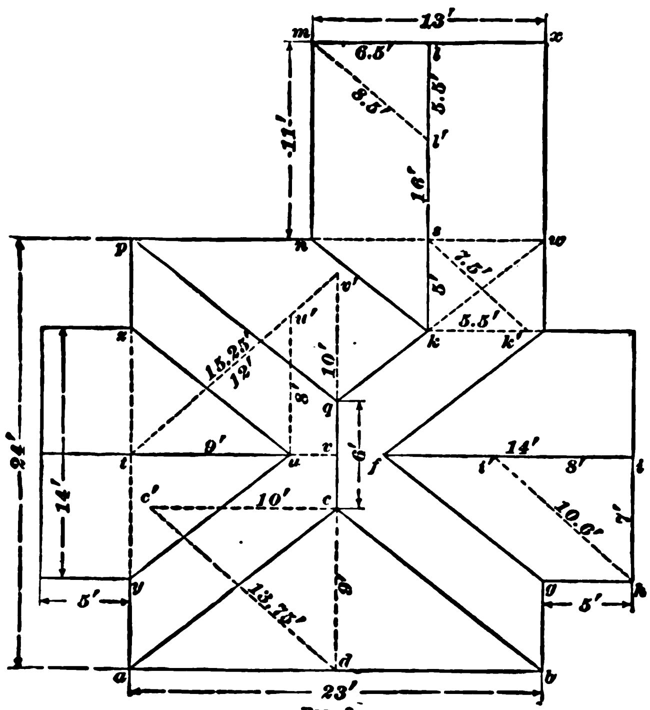


FIG. 8.

slope length of *d c*—found by laying off *c' c* equal to the height of the ridge above the eaves and drawing *c' d*—multiplied by the length of the eaves line *a b* and divided by 2. Multiplying the dimensions 13.75 feet and 23 feet, respectively, and dividing by 2, the area is found to be 158.1 square feet.

The area of the trapezoid *g f i h* is half the sum of *f i* and *g h*—shown in their true length on the plan—multiplied by the true length of *h i*. The latter is found by marking the

height of the gable ii' on the ridge line, and drawing the line $i'h$, which measures $10\frac{3}{4}$ feet. Performing these operations, there results $\frac{5+14}{2} \times 10\frac{3}{4} = 101.3$ square feet for each side, or 202.6 square feet for both. As the side gables are the same size, the area of the two roofs is $202.6 \times 2 = 405.2$ square feet.

The area of the polygon $qpnk$ is equal to the triangle qpw minus the triangle knw, the area covered by the intersecting gable roof. The former is equal to the triangle acb, the area of which is 158.1 square feet. The area of knw is equal to half of nw, or 6.5 feet, multiplied by the true altitude of the triangle; the latter is obtained by laying off kk' equal to the height of the gable, 5.5 feet, at right angles to ks, and drawing sk', which is the required altitude, and which measures 7.5 feet. Then $knw = 6.5 \times 7.5 = 48.7$ square feet; whence $qpnk$ equals $158.1 - 48.7 = 109.4$ square feet.

The area of $apqc$ is $\frac{ap+qc}{2}$ multiplied by the true slope length of tv, or tv', which measures 15.25 feet. Substituting dimensions, the area is found to be $\frac{6+24}{2} \times 15.25 = 228.7$ square feet. From this deduct the area of yzu, which is the portion covered by the intersecting gable roof. The true length of tu along the slope is tu', measuring 12 feet; hence the area of yzu is $\frac{14 \times 12}{2} = 84$ square feet. The net area of $apqc$ is, therefore, $228.7 - 84 = 144.7$ square feet; $bcqw$ being equal to $apqc$, its area is the same, making the area of both sides 289.4 square feet.

The area of $knml$ is $\frac{mn+lk}{2} \times ml'$, the slope length of ml. Substituting dimensions, the area is $\frac{11+16}{2} \times 8.5 = 114.7$ square feet. As $klxw$ is equal to $knml$, the area of both is 229.4 square feet.

Adding the partial areas thus obtained, the sum is $158.1 + 405.2 + 109.4 + 289.4 + 229.4 = 1{,}191.5$ sq. ft., or 11.9 squares.

PLASTERING.

36. Plastering on plain surfaces, such as walls and ceilings, is always measured by the square yard; but there are considerable variations in detail in the methods of measurement in different sections of the country. The following rules, however, probably represent the average practice, and are equitable to both parties concerned.

On walls and ceilings, measure the surface actually plastered, making no deduction for grounds, or for openings of less extent than 7 superficial yards.

Returns of chimney breasts, pilasters, and all strips of plastering less than 12 inches in width, measure as 12 inches wide.

In closets, add one-half to the actual measurement; if shelves are put up before plastering, charge double measurement.

For raking ceilings or soffit of stairs, add one-half to measurement; for circular or elliptical work, charge two prices; for surfaces of domes or groined ceilings, three prices.

Round corners and arrises (other than chimney breasts) should be measured by the lineal foot.

On interior work, increase the price 5 per cent. for each 12 feet above the ground after the first. For outside work, add 1 per cent. for each foot above the lower 20 feet.

All repairing and patching should be done at agreed prices.

37. Stucco Work.—Cornices composed of plain members and panel work are measured by the square foot. Enriched cornices with carved moldings are measured by the lineal foot. When moldings are less than 12 inches in girth, measurement is taken by the lineal foot; when over 12 inches, superficial measurement is used. For internal angles or miters, add 1 foot to length of cornice, and for exterior angles add 2 feet to length. Sections of cornice less than 12 inches measure as 12 inches. Add one-half for raking cornices.

For cornices or moldings abutted against wall or plain surface, add 1 foot to length of cornice; if against soffit of stairs or other inclined or covered surface, add 2 feet to length of cornice. Octagonal, hexagonal, and similar cornices, less than 10 feet in single stretches, take one and one-half times the length.

For circular or elliptical work charge double price; for domes and groins, three prices. Enrichments of all kinds should be estimated at an agreed price.

38. The quantity of plastering which can be done in a day varies considerably with the class of work, but for ordinary good 3-coat work, two plasterers, with one laborer to assist, should average from 60 to 70 square yards per day. The cost of the labor on 3-coat work, at about 25 cents per square yard, will be about 12 cents. For 2-coat work, at about 20 cents per square yard, the cost of the labor will be about 8 cents. Both of these figures on labor are exclusive of the cost of lathing. Where extremely fine work is demanded, these prices will be greatly increased.

The analyses of cost of 2 and 3 coat plastering, given in the complete example on estimating, are very carefully made, and may be relied on as bases for estimates.

LATHING.

39. Lathing is measured by the superficial yard, no openings under 7 superficial yards being deducted.

Plastering laths are about $1\frac{1}{2}$ inches wide, $\frac{1}{4}$ inch thick, and usually 4 feet long, the studding being generally placed 12 or 16 inches on centers, so that the ends of the lath may be nailed to them. The laths are usually set from $\frac{1}{4}$ to $\frac{3}{8}$ inch apart, requiring about $1\frac{3}{4}$ or $1\frac{1}{2}$ four-foot laths, respectively, to cover 1 square foot.

For a fair grade of work, a man will lay on an average about 15 bunches, or 1,500 laths, per day, while a rapid workman will put on about 2,000 laths. The cost of nailing up laths will be from 18 to 25 cents per bunch, or \$1.80 to \$2.50 per thousand, being about equal to the cost of the laths and nails.

JOINERY.

40. Joinery Details.—Joinery includes all the interior and exterior finish put in place after the framing and covering are completed; as, for example, door and window frames, doors, baseboard, paneling, wainscoting, stairs, etc. Most of these materials are worked at the mill and brought to the building ready to set in place.

Frames.—In taking off door and window frames, describe and state sizes. Measure architraves by the running foot, giving width and thickness, whether molded or plain, and state the number of plinth and corner blocks.

Sash.—State dimensions (giving the width first); thickness of the material, molded or plain; style of check-rail and sill finish; thickness of sash bar; whether plain, single or double hung; and sizes (giving dimensions in inches) and number of lights. Use standard sizes as much as possible.

Doors.—Describe and state the sizes and thickness, whether the framing is stuck-molded, raised-molded, or plain; and number of panels, whether plain or raised. Use stock sizes wherever possible and suitable.

Blinds.—Describe size and thickness; whether paneled or slatted (fixed or movable), and whether molded or plain.

Baseboard and Beam Casings.—Measure by the running foot, stating width and thickness of stuff, and whether molded or plain.

Wainscoting.—Measure by the superficial foot. State kind of finish, whether paneled or plain, and style of molding and panels. Wainscoting cap and base, measure by the running foot.

Stairways are generally taken by the contractor at so much per step, including everything complete according to the specifications. In measuring stairways, take off the amount of rough material in carriage timbers, and the

planed lumber in treads, risers, and strings. Measure balustrades by the lineal foot. Give size and style of treatment of newels. Measure spandrel and stairway paneling the same as wainscoting.

Kitchen dressers may be taken at a fixed price complete; or at a fixed rate per square foot; or as dressed lumber, drawers and doors being taken separately.

Wardrobes, bookcases, mantels, and *china closets* should be treated separately, and a fixed price stated.

Porches, exterior balustrades, balconies, porte cochères, etc. may be taken at a price per lineal foot, or the actual quantity of material may be measured.

DATA AND EXAMPLES OF ESTIMATING COSTS.

41. In any *molded work* which goes through the mill, the usual charge is *1 cent per square inch of section per lineal foot,* as a base, from which is deducted a percentage, generally from 40 to 60 per cent., depending on the grade of the material. For example, a $\frac{7}{8}$-inch (undressed thickness, 1 inch) door casing, 5 inches wide, will cost 1 cent × 5, less 50 per cent. = $2\frac{1}{2}$ cents per lineal foot.

Baseboard.—The cost of material and fitting in place may be estimated at 1 cent per square inch of section per lineal foot. This is for pine; if hard wood is used, double this price. The same rule applies also to chair rails, cap rails, and natural-finish picture molds.

Paneling may be estimated at 12 cents per square foot for 1-inch pine stuff; if over 1 inch, add simply for extra material. If the paneling is of hard wood and veneered, add 50 per cent. to the price of pine.

Plain *wainscoting* may be estimated at $6\frac{1}{2}$ cents per square foot, the cap being figured separately by the lineal foot.

42. Door Frames.—The following estimate represents the cost of an ordinary door frame:

COST OF DOOR FRAME IN PLACE.

Size, 2′ 8″ × 6′ 8″.

Jambs (rabbeted for doors), 13′ 6″; head jamb, 3′. Total jambs, 16½′ of 1⅛″ (1¼″) × 6″ clear-face material, at 1 cent per sq. in., per ft., less 50 per cent.	$0.62
Casing, 34½′ of ⅞″ (1″) × 5″, with ¼-round edge mold, at same rate	.86
Back-band molding, 34½′ of ⅞″ (1″) × 2″, at same rate as casing	.34
Plinth blocks, 4 pieces, 9″ × 1¾″ (2″) × 5¼″, at 1 cent per sq. in. per ft., less 50 per cent	.16
Dadoing and handsmoothing casing, back band, and plinth blocks	.50
Nails	.05
Putting together and setting up (2½ hours)	.65
Cost in place	$3.18

43. Doors.—The subjoined estimate gives the cost of a door of moderate price:

COST OF DOOR IN PLACE.

Size, 2′ 8″ × 6′ 8″. 1⅜ in. thick, 5 panels, double face, flat paneled, and stuck or solid molded.

Door delivered	$2.00
Fitting hinges and lock, hanging and trimming	.50
Butts, 1 pair 4 × 4, lacquered steel	.40
Mortise lock, brass face, and strike wood knob, bronze escutcheons	.80
Cost in place	$3.70

Cost per square foot, 21 cents.

If the door is hard wood and veneered, add 50 per cent. to price of the above, which is for a pine door. For curved doors in curved walls, the cost is about twice that of ordinary straight work.

A fair workman can hang, trim, and put hardware, including mortise lock, on about six ordinary doors per day. For veneered doors, or those requiring extra care, not more than three can be put in place.

44. Window Frame.—The following is approximately the cost of a window frame of the size mentioned:

COST OF WINDOW FRAME IN PLACE.

Size, 2 lights, $28'' \times 28''$.

Jambs, $12'$; head jamb, $3\frac{1}{2}'$; total, $15\frac{1}{2}'$. $15\frac{1}{2}' \times 1\frac{1}{8}''$ $(1\frac{1}{4}'') \times 5''$, at 1 cent per sq. in., per ft., less 50 per cent.	$0.48
Sill, $3\frac{1}{2}' \times 1\frac{1}{8}'' \times 5\frac{3}{4}''$, same rate	.13
Subsill, $4' \times 2'' \times 4''$, same rate	.16
Blind stop, $15\frac{1}{2}' \times \frac{7}{8}'' \times 2''$	.15
Parting strip, $14\frac{1}{2}' \times \frac{1}{2}'' \times 1''$	.04
Outside casing, $11\frac{1}{2}' \times 1\frac{1}{8}'' \times 5''$	.36
Head jamb, $4' \times 1\frac{1}{8}'' \times 7''$	.17
Cap, $4' \times 1\frac{1}{8}'' \times 3''$	.08
Molding, $4\frac{1}{2}'$ of $2\frac{1}{2}''$	.06
Sill nosing, $4' \times 1\frac{1}{8}'' \times 4'$	.10
Apron, $4' \times \frac{7}{8}'' \times 5''$	.10
Cove molding, $4'$ of $\frac{7}{8}''$	.06
Casing, $16\frac{1}{2}' \times \frac{7}{8}'' \times 5''$	.41
Back band, $16\frac{1}{2}' \times 1\frac{1}{8}'' \times 1\frac{1}{8}''$	.12
Sash stops, $14\frac{1}{2}' \times \frac{1}{2}'' \times 1\frac{1}{2}''$	.05
Labor, for frame complete, with outside casing attached at mill, and for setting inside casing at building	1.00
Cost in place	$3.47

45. Windows.—The cost of an ordinary window may be estimated as follows:

COST OF SASH IN PLACE.

Size, 2 lights, $28'' \times 28''$.

Cost of 2 sash, $1\frac{3}{4}''$ thick, at mill	$1.15
Glass, first quality, double-thick American, and setting	1.75
Sash weights, 35 lb., at 1 cent per lb.	.35
Cord for weights, $22\frac{1}{2}'$, at $\frac{1}{2}$ cent per ft.	.11
Sash lifts, 2	.05
Sash lock	.25
Hanging sash and putting on stops	.50
Cost in place	$4.16

For curved sash in curved walls, the cost is about twice that of straight work.

46. Stairs.—The cost per step for an ordinary stairway, constructed according to the following specifications, is about \$3.00. For a better class of work, add about one-quarter to this price. Length of steps, 3 feet; tread, Georgia pine; riser, white pine; open string, white pine; nosing and cove; dovetail balusters, square or turned; rail, $2\frac{1}{2}'' \times 3''$; 6-inch start newel, cherry; two 4-inch square angle newels, with trimmed caps and pendants; simple easements, furred underneath for plastering; treads and risers tongued together, housed into wall strings, wedged, glued, and blocked.

The material of such a stairway will cost about \$1.84 per step. This rate includes landing facia and balustrade to finish on upper floor. The labor on the same, mill work and setting in place, is about \$1.16 per step. For example, for a stairs having 17 steps and landing balustrade (including return, about 14 feet), the entire cost will be $17 \times \$3.00 = \$51.00$, of which \$31.28 will represent cost of dressed lumber, including turned balusters and newels, and worked rail; and \$19.72 will represent cost of labor in housing strings, cutting, mitering, and dovetailing steps, working easements, fitting and bolting rail, and erecting stairway in building.

47. Verandas.—For small dwellings, it has been found by experience that a veranda built on the following specifications will cost about \$2.25 per lineal foot: Width, 5 feet; posts, turned, set 6 or 8 feet on centers; floor timbers, $2'' \times 6''$; flooring, $\frac{7}{8}$-inch white pine, sound grade; rafters, $2'' \times 4''$ dressed; purlins, $2'' \times 4''$, set 2 feet on centers; roof sheathing, $\frac{7}{8}$-inch white pine; box frieze and angle mold; angle and face brackets; steps; no balustrade.

To include balustrade with 2-inch turned balusters, add about 60 cents per lineal foot.

For a veranda built according to the following specifications, the cost will be about \$4.00 per lineal foot: Width, 8 feet; columns, 9-inch, turned; box pedestals; box cornice and gutter; level ceiling; roof timbers, $2'' \times 6''$; roof covered

with matched boards; tin, a good grade; floor timbers, 2"×8"; floor, 1¼-inch white pine, second grade, with white-lead joints; no balustrade.

Including balustrade, with 2¼-inch turned balusters, rail, and base to suit, add 80 cents per lineal foot.

Where a portion of the veranda is segmental or semicircular, a close approximation to the cost will be had if the girth of the circular part is measured, and a rate fixed at twice that for straight work of the same length. This applies to veranda framing, roofing, casing, and balustrades.

HARDWARE.

48. Hardware is best estimated by noting the quantities required for each portion of the work as it is being measured, afterwards making these items into a separate hardware bill. Many of the articles, as, for example, the number of fixtures for doors or window trimmings, may be readily counted from the plans.

Hardware for windows, doors, etc. are sometimes included in estimating the cost per window, door, etc., and are not considered separately. In the estimates of such costs under "Joinery" (Arts. **43, 44,** and **45**), this method is followed; while in the complete example of estimating, given hereafter, the hardware is made into a separate bill.

The cost of the hardware depends entirely on the class of work and finish desired, and the best way to estimate on it is, after making the schedule, to select suitable designs and figure the prices from a catalogue.

An approximate estimate for the hardware in ordinary buildings is 1½ per cent. of the cost of the building. From 15 to 20 per cent. of the cost of hardware will pay for putting it in place.

HEATING AND VENTILATING SYSTEM.

49. Heating and ventilating work should be estimated as indicated in the following paragraphs.

Estimate all pipes and fittings same as for plumbing. Sum

up all standard radiators, and the price by square foot of radiation. Figure special radiators separately.

Itemize all valves, air vents, hangers, etc.

Estimate on pipe coverings by lineal foot.

Estimate sheet-metal indirect-radiator casings in pounds.

Estimate sheet-metal flues and smoke pipes by the lineal foot; but elbows and dampers separately.

Estimate register boxes, registers, and borders separately.

Make separate items of expansion tanks, hot-water damper regulators, and furnace regulators.

Figure heaters, steam boilers, and furnaces from manufacturer's catalogues.

In estimating on heating by furnace, the average cost of labor is about one-third that of materials. In steam and hot-water heating, the ratio is about one-fifth.

The cost of a hot-air installation is approximately 5 per cent. of the cost of the building; for steam heating, 8 per cent.; and for hot-water heating, 10 per cent.

PLUMBING AND GAS-FITTING.

50. Plumbing and gas-fitting work should be estimated as outlined in the following paragraphs:

PLUMBING.

51. An approximate figure for cost of plumbing is 10 per cent. of the cost of the building. This figure is for good materials and labor, and, of course, is subject to considerable variation. The cost of labor alone will average about one-fourth the cost of the materials.

52. Drainage System.—Measure all horizontal pipes from the plans, and vertical pipes from the sectional drawings.

Commence at the sewer outlet, and measure the main-sewer line forward into the building, and then measure the horizontal branches.

Measure the vertical, soil, waste, and vent stacks to their

terminations above the roof, and waste-pipe branches to the fixtures on the several floors.

Itemize the several pipes in the different kinds and classes.

Estimate all earthen pipe by the lineal foot, allowing for Portland cement in the joints.

Estimate all cast-iron pipe by the lineal foot, allowing for each joint $\frac{3}{4}$ pound of lead for every inch in diameter of the pipe.

Estimate wrought-iron pipe by the lineal foot, inclusive of couplings.

Estimate brass, copper, and lead pipe by the pound.

Estimate all traps, bends, branches, increasers, reducers, and other fittings separately, except such special brass fixtures, traps, and connections as are included in the cost of the fixtures. Do not figure lead bends which are smaller than 2 inches.

Estimate on brass-ferrule connections at all points where lead pipe joins iron pipe.

Estimate on all solder joints (wiped), allowing 1 pound of solder for every inch inside diameter of the pipe.

53. Water-Supply System.—For street supply, allow for permits, corporation tapping, and curb box.

Measure the service pipe from street main to cellar, and allow for a stop and waste cock, inside the cellar wall.

Measure all horizontal distributing pipes from the plans, and all vertical distributing pipes from the sectional drawings.

Measure all branches for the several fixtures on the different floors, to the lawn hydrants, etc.

Itemize the different kinds and classes of pipes.

Estimate lead, brass, and copper water pipes by the pound, and wrought-iron water pipe by the lineal foot.

Itemize all stop-cocks, pipe tacks, straps, hangers, etc. separately.

Estimate all water-pipe fittings less than $1\frac{1}{4}$ inches by the pound.

Figure on brass solder-nipple connections in all places where lead pipes join iron pipes.

Estimate on kitchen boiler, sediment cock, and range connections; and also faucets for all fixtures other than those which are included in the costs of the fixtures.

Estimate upon garden hydrants and lawn sprinklers, and allow a stop and waste cock in cellar for each.

54. Well Supply.—Figure on double-action force pump in kitchen or laundry, if well is not deeper than 26 feet below the pump; for a deep well, estimate on pumping engine or windmill.

Measure lead tank linings in square feet, and estimate by the pound, allowing 1 pound of solder for every 2 feet of seams.

Allow 2 feet of lead pipe to connect iron pipes to house tank, and for stop-cocks close to tank.

Provide for telltale and overflow pipes for tank.

Estimate copper tanks in square feet and by the pound, allowing 1 pound for each square foot.

If there are iron, slate, glass, or cedar tanks, figure them separately.

55. Fixtures.—Estimate each fixture separately, and include traps, faucets, waste, vent, and water connections to walls or floors. When the sewer is long and has but little fall, figure on using a grease trap for the kitchen sink.

GAS-FITTING.

56. Cost.—The cost of the gas-fitting may be approximately figured as about 3 per cent. of the cost of the building. The cost of labor alone varies from about one-fourth to one-seventh of the cost of materials. The better the grade of fixtures, the lower will be the ratio—provided there is no excessive ornamentation requiring much time to put in place—as the cost of the labor is about the same for cheap fixtures as for more costly ones.

57. Estimate piping the same as for plumbing.

Allow for meter, permits, tapping gas main, etc.

Figure each gas fixture separately set up in place. Owner

usually makes a selection of fixtures from manufacturer's catalogue. Allow for shields, fire-guards, etc., in places where there is danger of fire.

Figure gas grates, gas stoves, gas heaters, etc. separately. Where the gas pressure is very high or unsteady, allow for a pressure regulator.

PAINTING AND PAPERING.

PAINTING.

58. Painting is measured by the superficial yard, girting every part of the work that is covered by paint, and allowing additions to the actual surface to compensate for the difficulty of covering deep quirks of moldings, for carved and enriched surfaces, etc. Ordinary door and window openings are usually measured solid, to compensate for the extra time taken in working around them, "cutting in" the window sash, etc. Porch and stair balustrades, iron railings, and work having numerous thin strips, are also counted solid, for a like reason. Allowance is frequently made for distance from ground that the work is to be done, as in cornices, balconies, dormers, etc., and also for the difficulty of access.

Charges are usually made for each coat of paint put on, at a certain price per superficial yard and per coat.

Graining and marbling (imitations of wood and stone) and varnishing are rated at different prices from plain work.

Capitals and columns and other ornamental work which are difficult to measure should be enumerated, and a clear description of the amount of work on them should be given.

DATA ON PAINTING.

59. Quantities.—One pound of paint will cover from 3½ to 4 square yards of wood for the first coat, and from 4½ to 6 square yards for each additional coat; on brickwork, it will cover about 3 and 4 square yards, respectively. Colored paint will cover about one-third more surface than white paint.

Using prepared or ready-mixed paint, 1 gallon will cover from 250 to 300 square feet of wood surface, two coats; for covering metallic surfaces, 1 gallon will be sufficient for from 300 to 350 square feet, one coat. The weight per gallon of mixed paints varies considerably, but, on an average, may be taken at about 16 pounds.

Prepared shingle stains will cover about 200 square feet of surface per gallon, if applied with a brush; or this quantity will be sufficient for dipping about 500 shingles. Rough-sawed shingles will require about 50 per cent. more stain than smooth ones.

One pound of *cold-water* paint will cover from 50 to 75 square feet for first coat, on wood, according to surface condition, and about 40 square feet of brick and stone.

One gallon of liquid pigment filler, hard-oil finish, or varnish generally will cover from 350 to 450 square feet of surface for first coat, according to nature of wood and finish; and from 450 to 550 square feet for the second and subsequent coats. Ten pounds of paste wood filler will cover about 400 square feet.

One gallon of varnish weighs from 8 to 9 pounds; turpentine, about 7 pounds; and boiled or raw linseed oil, about $7\frac{3}{4}$ pounds.

For puttying, about 5 pounds will be sufficient for 100 square yards of interior and exterior work.

For sizing, about $\frac{1}{2}$ pound of glue is used to 1 gallon of water.

For mixing paints, the following figures represent the average proportions of materials required per hundred pounds of lead:

QUANTITIES OF MATERIALS.

Coat.	Lead. Pounds.	Raw Oil. Gal.	Japan Drier. Gal.
Priming	100	7	$\frac{3}{4}$
Second	100	6	..
Third	100	$6\frac{1}{2}$–7	..

The drier is omitted in the second and succeeding coats, unless the work is to be dried very rapidly, as it is considered to be injurious to the durability of the paint.

On outside work, boiled oil is generally used in about the proportion of 3 gallons to 2 gallons of raw oil.

60. Cost.—The cost of applying paint, on general interior and exterior work, will average about twice the cost of the materials; while for very plain work, done in one color, the cost may be taken at about $1\frac{1}{2}$ times that of the materials. For stippling, the cost will be about the same as for two coats of paint. For varnishing, the cost of labor will be about $1\frac{1}{2}$ times the price of the varnish.

The following figures represent fair average prices, for various classes of work, and have been adopted by the Builders' Exchange of a large eastern city:

INTERIOR WORK.	Cost per Square Yard.
1 coat paint, 1 color	12 cents
1 coat paint, 2 colors	15 cents
2 coats paint, 2 colors	20 cents
3 coats paint, 2 colors	25 cents
2 coats paint, 3 colors	25 cents
3 coats paint, 3 colors	32 cents
1 coat shellac	10 cents
Walls, 1 coat size, 2 coats paint	20 cents
Walls, 1 coat size, 3 coats paint stipple	30 cents
HARD-WOOD FINISH.	
1 coat paste filler, 1 coat varnish	30 cents
1 coat paste filler, 2 coats varnish	40 cents
1 coat paste filler, 3 coats varnish	50 cents
NATURAL FINISH.	
1 coat liquid filler, 1 coat varnish	20 cents
1 coat liquid filler, 2 coats varnish	25 cents
1 coat liquid filler, 3 coats varnish, rubbed	40 cents
Floors: filling, shellacking, varnishing, or waxing, 2 coats	35 cents

Tinting Walls.

Distemper Color.	Cost per Square Yard.
Tinting, 50 yards or less	9 cents
Tinting, 50 yards or more	7 cents
Patching and washing walls	7 cents

EXTERIOR PAINTING.

Woodwork.

1 coat, new work	10 cents
2 coats, new work, 2 colors	18 cents
2 coats, new work, 3 colors	20 cents
3 coats, new work, 2 colors	25 cents
3 coats, new work, 3 colors	28 cents

Brickwork.

1 coat	12 cents
2 coats	18 cents
3 coats	25 cents

Sanding.

2 coats paint, 1 coat sand	28 cents
3 coats paint, 1 coat sand	35 cents
3 coats paint, 2 coats sand	50 cents

Miscellaneous.

Dipping shingles, per 1,000	$3.00
Additional coat, per 1,000	.50
Blinds, per foot, 1 coat	.08
Fence, per foot, 1 coat, 4 feet high, wood	.12
Iron fence, per foot, 1 coat	.08
Tin roof, per yard, 1 coat	.05

PAPERING.

61. Papering is usually figured per roll, put on the wall. The paper is generally 18 inches wide, and is in 16-yard rolls. On account of waste in matching, etc., it is difficult to estimate very closely the number of rolls required, but an approximate result may be obtained as follows: Divide the perimeter of the room by $1\frac{1}{2}$ (the width of paper in feet);

the result will be the number of strips. Find the number of strips which can be cut from a roll, and divide the first result by the second; the quotient will be the number of rolls required. No openings less than 20 square feet in area should be deducted, in order to compensate for cutting and fitting at such places. Add about 15 per cent. to the area to allow for waste. The border, whether wide or narrow, is generally figured as 1 roll of paper.

The cost of paper is extremely variable, ranging from 15 cents to $6.00 per double roll; the average cost is probably 25 to 50 cents per roll, for ordinary houses. Paper hanging costs from 30 to 75 cents per double roll, with strips butted, the former figure being for the usual grade of work; with lapped strips, the cost is less, being from 20 to 25 cents per roll. Usually an extra charge is made for papering ceilings.

GLAZING.

62. Formerly glazing was included in the painter's contract, but as it is now usual and more convenient to glaze the sash at the mill when they are made, the glazing is included in the joinery specifications, and is not considered as a separate subdivision of estimating work. This method is followed in the example given hereafter.

In measuring glass, take the dimensions between rabbets each way, when the panes are rectangular; if irregular or circular in form, take the extreme dimensions, and consider the panes rectangular.

Polished plate glass is largely used for store-front windows, and also for glazing window sash in fine work. There are three qualities: French plate, and two grades of American plate, which may be obtained in panes varying in size from 1 inch square to 8 feet wide and 14 feet long. The cost of plate glass is estimated by the aid of a price list which gives the cost of the various sizes. This list remains the same from year to year, and is known as the standard list; the fluctuations are provided for by means of a discount, which is the same for all sizes of glass.

PANES OF WINDOW GLASS PER BOX.

Size. Inches.	Panes in Box.	Size. Inches.	Panes in Box.	Size. Inches.	Panes in Box.	Size. Inches.	Panes in Box.
6 × 8	150	12 × 19	32	16 × 20	23	24 × 44	7
7 × 9	115	12 × 20	30	16 × 22	20	24 × 50	6
8 × 10	90	12 × 21	29	16 × 24	19	24 × 56	5
8 × 11	82	12 × 22	27	16 × 30	15	26 × 36	8
8 × 12	75	12 × 23	26	16 × 36	12	26 × 40	7
9 × 10	80	12 × 24	25	16 × 40	11	26 × 48	6
9 × 11	72	13 × 14	40	18 × 20	20	26 × 54	5
9 × 12	67	13 × 15	37	18 × 22	18	28 × 34	8
9 × 13	62	13 × 16	35	18 × 24	17	28 × 40	6
9 × 14	57	13 × 17	33	18 × 26	15	28 × 46	6
9 × 15	53	13 × 18	31	18 × 34	12	28 × 50	5
9 × 16	50	13 × 19	29	18 × 36	11	30 × 40	6
10 × 10	72	13 × 20	28	18 × 40	10	30 × 44	4
10 × 12	60	13 × 21	26	18 × 44	9	30 × 48	5
10 × 13	55	13 × 22	25	20 × 22	16	30 × 54	5
10 × 14	52	13 × 24	23	20 × 24	15	32 × 42	5
10 × 15	48	14 × 15	34	20 × 25	14	32 × 44	5
10 × 16	45	14 × 16	32	20 × 26	14	32 × 46	5
10 × 17	42	14 × 18	29	20 × 28	13	32 × 48	5
10 × 18	40	14 × 19	27	20 × 30	12	32 × 50	4
11 × 11	59	14 × 20	26	20 × 34	11	32 × 54	4
11 × 12	55	14 × 22	23	20 × 36	10	32 × 56	4
11 × 13	50	14 × 24	22	20 × 40	9	32 × 60	4
11 × 14	47	14 × 28	18	20 × 44	8	34 × 40	5
11 × 15	44	14 × 32	16	20 × 50	7	34 × 44	5
11 × 16	41	14 × 36	14	22 × 24	14	34 × 46	5
11 × 17	39	14 × 40	13	22 × 26	13	34 × 50	4
11 × 18	36	15 × 16	30	22 × 28	12	34 × 52	4
12 × 12	50	15 × 18	27	22 × 36	9	34 × 56	4
12 × 13	46	15 × 20	24	22 × 40	8	36 × 44	5
12 × 14	43	15 × 22	22	22 × 50	7	36 × 50	4
12 × 15	40	15 × 24	20	24 × 28	11	36 × 56	4
12 × 16	38	15 × 30	16	24 × 30	10	36 × 60	3
12 × 17	35	15 × 32	15	24 × 32	9	36 × 64	3
12 × 18	33	16 × 18	25	24 × 36	8	40 × 60	3

When stained or art glass is used, the specifications generally limit the cost, as the glass is made according to the architect's designs.

Ordinary window or sheet glass is sold by the box, which contains, as nearly as possible, 50 square feet, whatever the size of the glass may be. There are two qualities of ordinary glass, known as *single* and *double thick*, the former being about $\frac{1}{16}$ inch thick, and the latter nearly $\frac{1}{8}$ inch. Single-thick glass should never be used in panes over 24 in. × 24 in. in size.

The foregoing table gives the number of panes of window glass in one box of 50 square feet.

EXAMPLE IN ESTIMATING.

63. Following the rules and suggestions already given in this section, the estimate for a house will be made as a practical example, the drawings on which it is based being shown in the accompanying plates. In making the estimate, the various portions of the work are taken in the order in which they naturally occur in the erection of the building, following, as closely as may be, the estimating schedule heretofore given.

The student is expected to take off the quantities and perform all the indicated work for himself, as far as possible, checking up the figures given in the example. It is only by actually making the calculations that he will derive any practical benefit from the work.

No two estimators, working separately, will arrive at exactly the same results; and the student, in following the calculations in this example, will doubtless find some discrepancies between his figures and the ones given. These should not be important ones, however, and by carefully studying the methods followed, he should obtain substantially the same results as those computed herein.

EXCAVATION.

64. In calculating the number of cubic yards of earth to be excavated for the cellar, all the measurements are taken from the foundation plan and the sections. The method

pursued in making calculations is as follows: The plan is blocked out as shown in the accompanying "Cellar Plan," and the area of each block is determined; then, by multiplying the sum of these partial areas by the depth of the cellar, the cubic contents are determined. The trenches for the foundation walls of porches and for the footings of cellar walls are calculated separately, as also are the excavations for piers, drains, cesspools, area, etc.

QUANTITIES.

Cellar Excavation.

		Sq. Ft.	Cu. Ft.
Block *A*, 23′ 4″ × 16′ 4″		381.0	
Block *B*, 14′ 6″ × 20′ 10″	302.0		
Add for projection of wall, $\frac{13'+7'}{2}\times 3' =$	30.0		
		332.0	
Block *C*, 27′ 6″ × 17′ 5″	479.0		
Deduct for breaks in wall, 1′ 7″ × 6′ 8″ and 2′ 6″ × 3′	18.0		
		461.0	
Block *D*, 26′ 6″ × 10′ 5½″		277.2	
Block *E*, 16′ 8″ × 11′ 6½″	192.4		
Deduct for breaks in wall, 6′ 6″ × 1′ 11″ and 3′ × 5″	13.7		
		178.7	
Block *F*, 9′ 10″ × 9′ 7½″ ÷ 2		47.3	
Block *G*, 14′ × 14′ × .7854 ÷ 2	77.0		
Deduct for portion of semicircular part, included in *F*, 12″ × 14′	14.0		
		63.0	
Total area of excavation		1,740.2	
Contents, 1,740.2 sq. ft. × 6.5 ft. (depth)			11,311.3

EXCAVATION FOR WALL FOOTINGS.
Lengths scaled along center line of walls:

	Sq. Ft.	Cu. Ft.
a b, 26′×2′ 6″	65.0	
b c, 5′ 6″×3′..........................	16.5	
c d, 9′ 9″×2′ 6″	24.4	
d e, 17′ 6″×2′ 6″..........................	43.7	
e f, 26′ 4″×2′ 6″..........................	65.8	
f g, 9′×3′ 8″..........................	33.0	
g h, 19′9″×2′ 6″	49.4	
i j, 27′ 7″×2′ 6″	69.0	
j a, 31′×2′ 6″	77.5	
k l (less openings), 18′ 9″×2′ 6″	46.9	
Chimney, 12′ 6″×4′ (approximately) 50		
Deductions.................... 10.4	39.6	
m n (less openings), 7′ 9″×2′ 6″..........	19.4	
o p, 19′ 6″×1′ 9″	34.1	
Total area of excavation for footings ..	584.3	
Contents, 584.3 sq. ft. ×10 in. (.833 ft.) depth..........................		486.7

MISCELLANEOUS EXCAVATIONS.
Lengths scaled along center line of walls:

		Cu. Ft.
Front porch, 69′ 9″×2′ 3″×3′....................		470.8
Back porch, 24′ 6″×2′×3′....................		147.0
Piers for steps, 1′ 9″×2′×3′×4....................		42.0
Piers for kitchen porch, 2′×2′×3′×2		24.0
Cellar area, 5′ 9″×6′×6′ 6″...............	224.2	
Deduct 1′ 9″×3′×6′ 6″...............	34.1	190.1
Dry cesspool, 6 ft. diameter×6 ft. depth.........		169.6
Cesspool, 6 ft. diameter×8 ft. depth.............		226.2
Trench for pipe to cesspool, 25′×7′ 6″×2′........		375.0
Trench for drain pipes (roof drainage), 228′×3′×1′		684.0
Trench for drain pipes from junction to dry cesspool, 20′×3′×18″		90.0
Total..................................		2,418.7
Grand total of excavation		14,216.7

FILLING.

	Cu. Ft.
Around foundation walls, 178′ 6″ × 6″ × 6′ 6″......	594.8
Around foundation of porches, 102′ × 6″ × 3′	153.0
Total filling............................	747.8

COST.

The cost of excavation is based on the following analysis:

Cost of 1 Cubic Yard of Excavation.

	Cents.
One man can pick 15 cu. yd. per day; wages being \$1.50, one yard will cost......................	10
One man can throw out 15 cu. yd. per day; wages being \$1.50, one yard will cost	10
One man with horse and cart can haul on a short haul 20 cu. yd. per day; wages being \$2.50, one yard will cost	12½
Cost per cubic yard.........................	32½

The cost of filling, including tamping, may be taken as about one-third that of excavation, or, say, 11 cents per cu. yd.

Summary.

Excavation, 14,216.7 cu. ft. = 526.5 cu. yd., at 32½ cents per cu. yd............................	\$171.11
Filling, 747.8 cu. ft. = 27.7 cu. yd., at 11 cents per cu. yd....................................	3.05
Total cost of excavation and filling.........	\$174.16

STONEWORK.

65. The foundation walls are built of rubble masonry to the sill at the grade line, and from this sill to the water-table they are built of ashlar with rubble backing, excepting those

portions behind porches which are wholly rubble. The estimate for stonework also includes the concrete for footings and cellar floor; the number of cubic feet of concrete required for the footings will be found by referring to the item "Excavation for Footings."

RUBBLE MASONRY.

Quantities.

(External measurements with no deduction for openings.)

		Cu. Ft.
Cellar walls, 178′ 6″×1′ 6″×6′ 6″		1,740.4
Add for extra thickness over 1′ 6″:		
5″×6′×6′ 6″	16.3	
1′ 2″×10′ 6″×6′ 6″	79.6	
		95.9
* Foundation walls for front porch:		
74′ 6″×1′ 4″×(average thickness) 2′ 6″		247.7
Foundation for steps:		
2 piers, 1′ 6″ square×2′ 6″	11.2	
2 piers, 2′ square×2′ 6″	20.0	
		31.2
Stone footings, under porch foundations, 74′ 6″ ×2′ 3″×6″		83.8
Backing for ashlar and water-table (see "Ashlar"), 78′×1′×3′		234.0
Rubble wall behind porches, 99′ 4″×1′ 6″×3′		447.0
* Foundation walls rear porch, 27′×1′ 6″×2′ 6″		101.2
Footings, walls rear porch, 27′×2′ 3″×6″		30.4
Area walls, 13′ 6″×12″×6′ 6″		87.7
Stone footing for area walls, 13′ 6″×18″×6″		10.1
Piers, 18″×18″×2′ 6″×2		11.3
Total rubble masonry		3,120.7

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* Although these are made continuous, to carry the base, or ground sill, independent piers under the porch columns might be substituted at a somewhat less cost.

Cost.

The estimate of cost of the rubble masonry is based on the following analysis:

Cost of 1 Perch of Rubble Masonry.

1 man can lay 3 perches per day; wages being \$2.50 per day, 1 perch will cost	\$0.83
3 laborers are required for 4 masons; wages being \$1.50 per day, 1 perch will cost	.38
Stone, delivered at work	1.25
⅙ load sand, at \$1.50 per load	.25
½ barrel Rosendale cement, at \$1.25 per bbl	.63
Total cost of 1 perch	\$3.34

Summary.

From the foregoing calculation, the quantity of rubble masonry is 3,120.7 cu. ft. Taking 25 cu. ft. to 1 perch, 3,120.7 ÷ 25 = 124.8 perches, which at \$3.34 per perch makes the total cost of rubble masonry	\$416.83

ASHLAR.

The walls between base sill and water-table are faced with ashlar, which extends around main walls to porches, and all porch piers are built of ashlar.

Quantities.

	Sq. Ft.
Facing for cellar walls, 78 lineal ft. × 2 ft. 3 in.	175.5
Porch piers, 29¼ lineal ft. × 2 ft. 3 in.	65.8
Total ashlar	241.3

Cost.

The estimated cost of ashlar is based on the following analysis:

Cost of 1 Square Foot of Ashlar.

Cost of stone, bluestone facing	$0.30
Hauling stone, say $\frac{1}{10}$ of cost of stone	.03
Mortar	.01
Labor, estimating 80 sq. ft. per day for 2 masons and 1 laborer:	
2 masons, at $3 per day	.075
1 laborer, at $1.50 per day	.02
Cost per square foot	$0.44

Summary.

From the foregoing quantities, the ashlar amounts to 241.3 square feet, which, at 44 cents per square foot, will make the total cost of ashlar.	$106.17

CUT STONE.

Quantities and Cost.

	Cost per Ft.	Total Cost.
Base, or ground sill, extending under porches (except under stone steps) and along exposed main walls, 172 ft., 5″×11″ and 6″×8″ dressed and chamfered sandstone	$0.60	$103.20
Water-table, extending around main walls, 178 ft. 6 in., 6″×10″ dressed and chamfered sandstone	.60	107.10
Lintel course, extending over brick walls, 125 lineal ft., 6″×10″ dressed sandstone	.60	75.00
12 dressed sandstone window sills, cut with lug and drip, 5″×8″, 55¾ lineal ft.	.60	33.45

	Cost per Ft.	Total Cost.
Cut-stone jambs for main door, 10″×10″, 19½ lineal ft.	$1.75	$34.13
1 door sill, 6″×10″, 5¾ lineal ft.	1.00	5.75
Coping on area walls, 3″×16″, 12 lineal ft.	.60	7.20
Porch steps, 8″×12″, 57 lineal ft., dressed sandstone	1.25	71.25
9 bluestone steps, for outside cellar entrance, 4′×12″×2″	.25	9.00
Bluestone lintel for kitchen fireplace, 6′×12″×6″	1.00	6.00
Cut stone for main chimney		15.00
Labor, setting lintels, sills, etc.:		
1 mason, 8 days, at $3.00 per day		24.00
2 laborers, 8 days each, at $1.50 per day.		24.00
Total cost of cut stone		$515.08

CONCRETE FOOTINGS AND FLOOR.

Quantities.

Footings, as per "Excavation for Footings," 486.7 cu. ft. ÷ 27 .... 18.3 cu. yd

	Sq. Ft.
Concrete floor:	
Area of cellar excavation	1,740.2
Deduct area of footings	584.3
	1,155.9
Add for 6-inch strip over inner projection of wall footings, 165′×6″	82.5
Add for projection on both sides of interior walls, 79′×6″	38.5
Add for projection over chimney footing, 31′ 6″	15.5
Total area of concrete floor,	1,292.4 = 143.6 sq. yd.

Cost.

The estimates for concrete footings and floor are based on the following analyses of costs:

Cost of 1 Cubic Yard of Concrete.

1 barrel of Rosendale cement	$1.25
3 barrels of sand, or ½ load, at $1.50 per load	.50
1 cu. yd. (about 6 barrels) of broken stone	1.50
Mason, ¼ day, at $2.50	.62
Laborer, 1 day, at $1.50	1.50
Total	$5.37

Cost of 1 Square Yard of Cellar Floor.

Concrete, 4½ inches thick, at $5.37 per cubic yard	$0.67
Sand bed, 6 inches thick, approximately 1 barrel	.17
Spreading sand	.03
$\frac{1}{12}$ barrel of Portland cement for ½-inch finishing coat, at $2.60 per barrel	.21
$\frac{1}{12}$ barrel of white sand, at $1.00 per barrel	.08
Mixing and spreading surface layer	.08
Cost per square yard	$1.24

Summary.

Footing concrete, as per foregoing figures, 18.3 cu. yd. at $5.37 per cu. yd.	$98.27
Concrete floor, 143.6 sq. yd. at $1.24 per sq. yd.	178.06
Total cost of concrete	$276.33

RECAPITULATION OF COST OF STONEWORK.

Rubble masonry	$416.83
Ashlar masonry	106.17
Cut stone	515.08
Concrete footings and floor	276.33
Total cost of stonework	$1,314.41

BRICKWORK.

66. In estimating the brickwork, openings have been deducted, thus practically giving "kiln count," so that the analyses of prices given heretofore will apply. If openings had not been deducted, the prices would have been decreased 15 per cent., as before noted.

PRESSED BRICK.

Quantities.

	Sq. Ft.	No. Brick.
Facing exterior walls, same length as stone lintel course, 125′×8′ 9″ = 1,093.8 sq. ft., at $7\frac{1}{2}$ bricks per sq. ft.		8,203
Deduct for openings:		
9 windows, total width 32′×6′ 6″ high	208.0	
2 casement windows, total width 7′ 4″×8′ high	58.7	
1 lavatory window, total width 2′ 6″×5′ 6″	13.7	
Main door, 3′ 5″×8′ 6″	29.1	
Total deductions	309.5	
$309.5\times7\frac{1}{2}$ =		2,321
No. of brick		5,882
Add 5 per cent. for waste		294
Total pressed brick		6,176

Cost.

The cost of pressed brickwork is based on the following analysis:

Cost of 1,000 Pressed Brick in Place.

	Cost per M.
1,000 pressed bricks, delivered	\$30.00
1 bricklayer can lay 300 pressed brick per day of 9 hours, or 1,000 will require 30 hours; wages being 40 cents per hour	12.00
1 laborer to 2 men, 15 hours, at 15 cents per hour	2.25
$\frac{1}{2}$ barrel of lime	.38
$\frac{1}{4}$ load of sand	.37
Total	\$45.00

Summary.

From the preceding estimate of quantities, the number of pressed brick laid is 5,882, which, at \$45.00 per M, will cost	\$264.69
Pressed brick, not laid, 294, at \$30.00 per M	8.82
Total cost of pressed brickwork	\$273.51

COMMON BRICK.

Quantities.

		No. Brick.
Backing exterior pressed-brick walls, $8\frac{1}{2}''$ thick, 5,882×2 =		11,764
Interior cellar walls, 28′×8′ = 224 sq. ft. (17-inch wall) at 30 brick per sq. ft.	6,720	
Deduct for 3 openings, 12′ 6″ total width × 6′ 6″ height = $81\frac{1}{4}$ sq. ft. at 30 brick per sq. ft.	2,437	4,283
Interior wall, $8\frac{1}{2}''$ thick, 19′ 9″×8′, 158 sq. ft. at 15 brick per sq. ft.		2,370
Chimney, principal (flues figured solid), approximately 920 cu. ft., at $22\frac{1}{2}$ brick per sq. ft.		20,700
Chimney, rear, approximately 245 cu. ft., at $22\frac{1}{2}$ brick per sq. ft.		5,512.5
Trap pits, 46 sq. ft., at $7\frac{1}{2}$ brick per sq. ft.		345
		44,974
Add 5 per cent. for waste		2,249
Total common brick		47,223

Cost.

The cost of the common brickwork is based on the following analysis:

Cost of 1,000 Common Brick in Place.

	Cost per M.
1,000 brick, delivered	$6.00
1 bricklayer can lay 1,000 brick in 7 hours; wages being 35 cents per hour, the cost of laying 1,000 is	2.45
1 helper, 7 hours, at 15 cents per hour	1.05
3 bushels of lime, at 25 cents per bushel	.75
$\frac{1}{2}$ load of sand, at $1.50 per load	.75
Total	$11.00

Summary.

According to the estimate of quantities, the number of common brick laid is 44,974, which, at $11.00, will cost	$494.71
Common bricks, not laid, 2,249, at $6.00	13.49
Molded brick and terra-cotta cap for rear chimney.	10.00
Total cost of common brickwork	$518.20

RECAPITULATION OF COST OF BRICKWORK.

Pressed brickwork	$273.51
Common brickwork	518.20
Total cost of brickwork	$791.71

CARPENTRY.

FRAMING.

67. In estimating carpentry work, it is advisable to make a tabulated list of the various sizes of joists, rafters, etc., giving the number and dimensions of each set. Thus any error in calculation or change in price can be corrected with little difficulty.

Quantities.

Floor Framing, First Story.

	Lineal Ft.	Ft. B. M.
Joists, 3″×10″; 2½ ft. B. M., per lineal ft.:		
6 pieces, each 14′ 6″	87.00	
2 pieces, each 15′ 3″	30.50	
1 piece, 16′ 3″	16.25	
5 pieces, each 17′ 6″	87.50	
1 piece, 12′ 6″	12.50	
6 pieces, each 11′ 0″	66.00	
1 piece, 9′ 6″	9.50	
18 pieces, each 14′ 0″	252.00	
1 piece, 11′ 6″	11.50	
3 pieces, each 10′ 6″	31.50	
1 piece, 9′ 4″	9.33	

	Lineal Ft.	Ft. B. M.
6 pieces, each 24′ 0″	144.00	
1 piece, 11′ 4″	11.33	
2 pieces, each 20′ 6″	41.00	
6 pieces, each 20′ 0″	120.00	
4 pieces, each 21′ 0″	84.00	
2 pieces, each 7′ 0″	14.00	
2 pieces, each 13′ 0″	26.00	
1 piece, 10′ 0″	10.00	
Total	1,063.91	2,659.78

Floor Framing, Second Story.

	Lineal Ft.	Ft. B. M.
Girder, 6″×12″; 6 ft. B. M., per lineal ft.:		
1 piece, 8′ 9″	8.75	52.50
Joists, 2″×10″; 1⅔ ft. B. M., per lineal ft.:		
15 pieces, each 14′ 0″	210.00	
2 pieces, each 15′ 6″	31.00	
5 pieces, each 17′ 0″	85.00	
3 pieces, each 15′ 0″	45.00	
14 pieces, each 16′ 0″	224.00	
2 pieces, each 7′ 0″	14.00	
2 pieces, each 10′ 0″	20.00	
4 pieces, each 11′ 0″	44.00	
7 pieces, each 24′ 0″	168.00	
3 pieces, each 20′ 6″	61.50	
4 pieces, each 12′ 6″	50.00	
2 pieces, each 13′ 6″	27.00	
Total	979.50	1,632.50
Joists, 3″×10″; 2½ ft. B. M., per lineal ft.:		
(Headers) 2 pieces, each 8′ 9″	17.50	
2 pieces, each 6′ 0″	12.00	
5 pieces, each 9′ 9″	48.75	
11 pieces, each 19′ 6″	214.50	
	292.75	731.87

Floor Framing, Attic.

	Lineal Ft.	Ft. B. M.
Joists, 2″×10″; $1\frac{2}{3}$ ft. B. M., per lineal ft.:		
15 pieces, each 14′ 0″	210.00	
2 pieces, each 15′ 6″	31.00	
5 pieces, each 17′ 0″	85.00	
3 pieces, each 15′ 0″	45.00	
14 pieces, each 16′ 0″	224.00	
2 pieces, each 7′ 0″	14.00	
2 pieces, each 10′ 0″	20.00	
4 pieces, each 11′ 0″	44.00	
7 pieces, each 24′ 0″	168.00	
3 pieces, each 20′ 6″	61.50	
4 pieces, each 12′ 6″	50.00	
2 pieces, each 13′ 6″	27.00	
Total........................	979.50	1,632.50

	Lineal Ft.	Ft. B. M.
Joists, 3″×10″; $2\frac{1}{2}$ ft. B. M., per lineal ft.:		
2 pieces, each 8′ 9″	17.50	
2 pieces, each 6′ 0″	12.00	
5 pieces, each 9′ 9″	48.75	
11 pieces, each 19′ 6″	214.50	
Total........................	292.75	731.87

Floor Framing, Front Porch.

	Lineal Ft.	Ft. B. M.
Joists, 3″×9″; $2\frac{1}{4}$ ft. B. M., per lineal ft.:		
3 pieces, each 7′ 0″	21.00	
1 piece, 6′ 9″	6.75	
2 pieces, each 10′ 0″	20.00	
1 piece, 8′ 6″	8.50	
[illegible]	56.25	126.56

	Lineal Ft.	Ft. B. M.
Joists, 2″×6″; 1 ft. B. M., per lineal ft.:		
2 pieces, each 21′ 6″..............	43.00	
2 pieces, each 19′ 3″..............	38.50	
4 pieces, each 8′ 0″..............	32.00	
1 piece, 10′ 3″..............	10.25	
6 pieces, each 9′ 0″..............	54.00	
2 pieces, each 4′ 6″..............	9.00	
5 pieces, each 6′ 0″..............	30.00	
4 pieces, each 5′ 0″..............	20.00	
3 pieces, each 2′ 0″..............	6.00	
3 pieces, each 9′ 0″..............	27.00	
Total........................	269.75	269.75

Floor Framing, Back Porches.

	Lineal Ft.	Ft. B. M.
Joists, 2″×6″; 1 ft. B. M., per lineal ft.:		
2 pieces, each 21′ 0″..............	42.00	
3 pieces, each 8′ 0″..............	24.00	
Total........................	66.00	66.00
Joists, 3″×6″; $1\frac{1}{2}$ ft. B. M., per lineal ft.:		
5 pieces, each 5′ 9″..............	28.75	
12 pieces, each 6′ 9″..............	81.00	
1 piece, 8′ 6″..............	8.50	
2 pieces, each 3′ 6″..............	7.00	
Total........................	125.25	187.87

Bridging.

	Lineal Ft.	Ft. B. M.
2″×4″; $\frac{2}{3}$ ft. B. M., per lineal ft.:		
First floor, 170 pieces, each 1′ 6″...	255.00	
Second floor, 138 pieces, each 1′ 6″.	207.00	
Third floor, 138 pieces, each 1′ 6″..	207.00	
Total........................	669.00	446.00

Main Roof Framing.

	Lineal Ft.	Ft. B. M.
Rafters, 2″×6″; 1 ft. B. M., per lineal ft.:		
15 pieces, each 20′ 0″	300.00	
14 pieces, each 19′ 3″	269.50	
1 piece, 18′ 0″	18.00	
2 pieces, each 16′ 0″	32.00	
2 pieces, each 14′ 0″	28.00	
1 piece, 13′ 4″	13.33	
3 pieces, each 10′ 6″	31.50	
3 pieces, each 8′ 6″	25.50	
1 piece, 6′ 9″	6.75	
3 pieces, each 5′ 0″	15.00	
3 pieces, each 3′ 0″	9.00	
4 pieces, each 17′ 0″	68.00	
1 piece, 12′ 6″	12.50	
1 piece, 10′ 9″	10.75	
2 pieces, each 9′ 0″	18.00	
1 piece, 7′ 0″	7.00	
18 pieces, each 9′ 6″	171.00	
2 pieces, each 13′ 0″	26.00	
2 pieces, each 7′ 9″	15.50	
2 pieces, each 6′ 6″	13.00	
4 pieces, each 3′ 6″	14.00	
2 pieces, each 2′ 0″	4.00	
4 pieces, each 8′ 0″	32.00	
2 pieces, each 11′ 0″	22.00	
8 pieces, each 5′ 3″	42.00	
1 piece, 6′ 0″	6.00	
8 pieces, each 11′ 0″	88.00	
Total	1,298.33	1,298.33
Valley rafter, 3″×10″; 2½ ft. B. M., per lineal ft.:		
1 piece, 24′ 6″		61.25
Ridge plates, 2″×10″; 1⅔ ft. B. M., per lineal ft.:		

	Lineal Ft.	Ft. B. M.
1 piece, 23′ 6″	23.50	
1 piece, 29′ 3″	29.25	
1 piece, 9′ 0″	9.00	
Total	61.75	102.92
Plates, 3″×6″; $1\frac{1}{2}$ ft. B. M., per lineal ft.:		
4 pieces, each 10′ 6″		63.00
Octagonal post, 6″×6″×3′		9.00

Porch-Roof Framing.

	Lineal Ft.	Ft. B. M.
Rafters, 2″×6″; 1 ft. B. M., per lineal ft.:		
2 pieces, each 9′ 6″	19.00	
22 pieces, each 8′ 6″	187.00	
4 pieces, each 6′ 6″	26.00	
8 pieces, each 7′ 0″	56.00	
2 pieces, each 11′ 0″	22.00	
Total	310.00	310.00
Rafters, 2″×5″; $\frac{5}{6}$ ft. B. M., per lineal ft.:		
27 pieces, each 8′ 0″	216.00	
8 pieces, each 6′ 6″	52.00	
2 pieces, each 10′ 6″	21.00	
2 pieces, each 3′ 0″	6.00	
2 pieces, each 3′ 6″	7.00	
Total	302.00	251.65
Plate, 5″×10″; $4\frac{1}{6}$ ft. B. M., per lineal ft.:		
5 pieces, each 15′ 0″	75.00	312.50
Sills, 3″×5″; $1\frac{1}{4}$ ft. B. M., per lineal ft.:		
2 pieces, each 10′ 0″	20.00	
5 pieces, each 9′ 0″	45.00	
Total	65.00	81.25

Wall Studding.

	Lineal Ft.	Ft. B. M.
Wall plates, 4″×11″; 3⅔ ft. B. M., per lineal ft.:		
10 pieces, each 18′ 0″	180.00	660.00
Studs, 2″×5″; ⅚ ft. B. M., per lineal ft.:		
63 pieces, each 21′ 0″	1,323.00	
106 pieces, each 12′ 0″	1,272.00	
20 pieces, each 20′ 0″	400.00	
10 pieces, each 8′ 6″	85.00	
Total	3,080.00	2,566.66

Partition Studding.

	Lineal Ft.	Ft. B. M.
First floor, 2″×4″; ⅔ ft. B. M., per lineal ft.:		
Studs, 160 pieces, each 9′ 9″	1,560.00	
Sills, 16 pieces, each 15′ 0″	240.00	
Total	1,800.00	1,200.00
Second floor, 2″×4″; ⅔ ft. B. M., per lineal ft.:		
Studs, 180 pieces, each 9′ 9″	1,755.00	
Sills, 10 pieces, each 15′ 0″	150.00	
Total	1,905.00	1,270.00
Attic, 2″×4″; ⅔ ft. B. M., per lineal ft.:		
Studs, 54 pieces, each 8′ 9″	472.50	
Studs, 133 pieces, each 6′ 6″	864.50	
Total	1,337.00	891.33

Miscellaneous.

	Lineal Ft.	Ft. B. M.
Lookouts:		
50 pieces, each 3″×1″×2′		25.00
37 pieces, each 6″×1″×2′		37.00
Furring, for brick walls, 1″×2″; ⅙ ft. B. M., per lineal ft.:		
125 pieces, each 11′ 0″	1,375.00	229.16
Grand total of framing.		17,906.25

Cost.

The cost of the framing is estimated with the following analysis as a basis:

Cost of 1,000 Feet B. M. of Hemlock.
(Including framing.)

1,000 ft. of hemlock	$14.00
Nails and spikes, allowing 100 lb. to 3,000 ft. of lumber, at $1.80 per 100 lb.	.60
Labor, taking 50 per cent. of the cost of material as cost of framing	7.00
Cost per thousand feet B. M.	$21.60

Summary.

The amount of material, as previously estimated, is 17,906.25 ft. B. M., which, at $21.60 per M, will make the total cost of framing	$386.77

SHEATHING AND SHINGLES.

Quantities.

Sheathing.

	Ft. B. M.
Main roof, 2,200 sq. ft. × 1 in.	2,200.00
Tower roof, 370 sq. ft. × 1 in.	370.00
Porch roof, 637 sq. ft. × 1 in.	637.00
Outside walls, 2,417 sq. ft. × 1 in.	2,417.00
Total sheathing	5,624.00

Shingles.

Area to be covered (see wall sheathing), 2,417 sq. ft. = 24.2 squares.

Shingles, 4 in. wide, and 5 in. exposure, number per square	720	
Number of shingles required, 24.2 × 720		17,424
Add 5 per cent. for waste		871
Total shingles		18,295

Cost.

The cost of sheathing in place is assumed to be the same as that for hemlock lumber, \$21.60 per M. The total sheathing is 5,624 square feet, which, at \$21.60 per M, will make the cost of sheathing	\$121.48

The cost of shingles is based on the following analysis:

Cost of 1,000 Shingles in Place.

1,000 shingles XXX	\$5.00
Labor: one man can lay about 1,500 shingles per day; wages being \$2.25, 1,000 will cost	1.50
Nails (about)	.25
Cost per thousand	\$6.75

From the preceding estimate, the number of shingles required is 18,295, which, at \$6.75 per 1,000, will make the cost of shingles in place	\$123.49

Summary.

Sheathing	\$121.48
Shingles	123.49
Total cost of sheathing and shingles	\$244.97

FLOORING.

Quantities.

	Sq. Ft.
First floor, area (net)	1,312
Second floor, area (net)	1,312
Attic floor, area (net)	1,071
Porch floors, area (net)	5,523

Hemlock Under Flooring.

	Ft. B. M.
Adding 25 per cent. to the net areas to allow for matching and waste, the quantity of $\frac{7}{8}$-inch rough flooring required for the first two floors is $2,624 + (2,624 \times .25) =$	3,280

White-Pine Finish Flooring.

	Ft. B. M.
The total area of the first, second, and third floors is 3,695 square feet. Adding 25 per cent. for waste, the quantity of $\frac{7}{8}$-inch flooring is 3,695 sq. ft. + (3,695 × .25) =	4,619

Yellow-Pine Porch Flooring.

Increasing the net area of the porch floor by 25 per cent., the flooring required is 523 sq. ft. + (523 × .25) =	654

Cost.

The estimated cost of flooring may be analyzed as follows:

Cost of 1,000 Feet B. M., Rough Flooring.

1,000 ft. B. M., hemlock	$17.00
Labor, 50 per cent. of cost of lumber	8.50
Nails, 33 lb., at $1.80 per 100 lb.	.60
Cost per thousand feet B. M.	$26.10

Cost of 1,000 Feet B. M., Finish Flooring.

1,000 ft. B. M., No. 2 white pine	$22.00
Labor, 50 per cent. of cost of lumber	11.00
Nails	.60
Cost per thousand feet B. M.	$33.60

Cost of 1,000 Feet B. M., Porch Flooring.

1,000 ft. B. M., No. 2 yellow pine	$20.00
Labor	10.00
White lead for joints (about)	.50
Nails	.60
Cost per thousand feet B. M.	$31.10

Summary.

Hemlock, 3,280 ft. B. M., at $26.10 per M	$85.61
White pine, 4,619 ft. B. M., at $33.60 per M	155.19
Yellow pine, 654 ft. B. M., at $31.10 per M	20.34
Total cost of flooring	$261.14

MISCELLANEOUS ITEMS.

Quantities.

Yellow-Pine Lumber.

	Ft. B. M.
Porch ceiling, same as porch flooring	654

No. 1 White-Pine Dressed Lumber.

Cornice, 393 ft. × 2 ft. 6 in. (the combined width of the plain members) × 1¼ in. thick	1,228
Spandrels, 357 sq. ft., 1 in. thick	357
Base, 128 lin. ft. × 6 in. × 1 in.	64
16 porch posts, 9 ft. × 8 in. × 8 in.	768
Total	2,417

Cost.

The cost of yellow-pine ceiling is the same as that for yellow-pine flooring, less cost of white lead for joints, or $30.60.

The cost of No. 1 white-pine lumber may be analyzed as follows:

Cost of 1,000 Feet B. M. of Planed Lumber.

No. 1 white pine, $30.00 per M	$30.00
Labor, 50 per cent. of cost of lumber	15.00
Nails, 33 lb., at $1.80 per 100 lb.	.60
Cost per thousand feet B. M.	$45.60

Summary.

654 ft. B. M., yellow-pine ceiling, at $30.60 per M	$20.01
2,417 ft. B. M., white-pine dressed lumber, at $45.60 per M	110.21
Total cost of miscellaneous items	$130.22

RECAPITULATION OF COST OF CARPENTRY.

Framing	$386.77
Sheathing and shingles	244.97
Flooring	261.14
Miscellaneous items	130.22
Total cost of carpentry	$1,023.10

ROOFING.

FRAMING AND SHEATHING.

68. Roof framing and sheathing are included in the estimate for carpentry.

SLATING.

Quantities.

Quantities.	Squares.
Main and dormer roofs	22.0
Porch roof	6.4
Tower roof, 370 sq. ft.	3.7

Cost.

The cost of slating may be estimated as follows:

Cost of 1 Square of Slating.	Per Square.
Slates, 8″ × 12″ (6″ × 12″, $4.00)	$5.00
Labor: 1 slater will average 2 squares per day; wages being $2.00 per day, 1 square will cost.	1.00
Nails: 8″ × 12″ slates require 5 lb. 9 oz. (5.6 lb.) of galvanized nails per square, which, at $2.20 per 100 lb., cost	.12
(6″ × 12″ require 7 lb. 6 oz., or 7.4 lb., costing 16 cents.)	
Roofing felt, 1 roll	2.40
Labor and nails for laying felt	.15
(Flashing, etc., itemized separately.)	
Cost per square	$8.67

Summary.

Main, dormer, and porch roofs, 28.4 squares, at $8.67 per square	$246.22
Tower roofs, 3.7 squares of 6″ × 12″ slates at $8.21 per square (cost per square for labor, $1.50, to compensate for extra work in cutting, etc.)	30.38
Cost of slating	$276.60

MISCELLANEOUS ITEMS.

Quantities and Cost.

Tin roof on bay window, 38 sq. ft., at 11 cents per sq. ft.	$4.18
Tin for valleys, 191 sq. ft., at 10 cents per sq. ft.	19.10
Flashing around chimneys and dormers, 90 sq. ft., at 10 cents per sq. ft.	9.00
Gutters, 100 lin. ft., 26 in. wide, at $21\frac{1}{2}$ cents per ft.	21.50
Conductor pipe, 4-inch galvanized iron, 146 lin. ft., at 20 cents per lin. ft.	29.20
Terra-cotta ridge tiles, 70 lin. ft., at 40 cents per lin. ft.	28.00
Terra-cotta finials, 3, 2 ft. high, at $6.00 each	18.00
Tower finial, copper	10.00
Total	$138.98

(Labor included in above prices.)

RECAPITULATION OF COST OF ROOFING.

Slating	$276.60
Miscellaneous	138.98
Total cost of roofing	$415.58

PLASTERING.

69. Plastering varies in price according to its position and quality. It is therefore necessary to make a separate schedule of each class of work, so that any increase or decrease in quantity may be easily added to or deducted from the estimate.

Quantities.

Three-Coat Work.	Sq. Ft.	Sq. Yd.
First-story walls, $542' \times 9' 9\frac{3}{8}''$	5,284.5	
First-story ceiling (take measurement of flooring)	1,312	
Second-story walls, $609' \times 9'$	5,481	
Second-story ceiling	1,312	
Attic walls, $190' \times 8' + 156' \times 6'$	2,456	
Attic ceiling	831	
Total of three-coat plastering	16,676.5	1,853

Two-Coat Work.

	Sq. Ft.	Sq. Yd.
Cellar ceiling, use same measurements as for concrete cellar floor		143.6

Cornices.

Cornice, 147′×2′ girth	294	
Cornice, 493′×1′ girth	493	
Total sq. ft. of cornice	787	

Cost.

The cost of the plastering is based on the following analyses:

Cost of 100 Square Yards of Three-Coat Plastering.

1,440 laths, 1½ in. wide, ⅜ in. spacing, at $2.10 per 1,000	$3.02
10 lb. 3d. nails, at $2.05 per 100 lb.	.20
Labor: putting on lath, carpenter, 1 day	2.25
13 bushels of lime, at 25 cents per bushel	3.25
1 bushel of hair, 8 lb., at 4 cents per lb.	.32
1½ loads of plastering sand, at $1.50 per bushel	2.25
⅓ barrel of plaster of Paris, at $1.50 per barrel	.50
Labor:	
Plasterer, 3¼ days, at $3.00 per day	9.75
Helper, 2½ days, at $1.50 per day	3.75
Cartage	1.00
Total	$26.29

Cost per sq. yd., $26.29 ÷ 100 = 26 cents, approximately.

Cost of 100 Square Yards of Two-Coat Plastering.

Cost of lath, nails, and carpenter work, same as for three-coat work	$5.475
10 bushels of lime, at 25 cents per bushel	2.50
¾ bushel, or 6 lb., of hair, at 4 cents per lb.	.24
1 load of sand	1.50
⅓ barrel plaster of Paris, at $1.50	.50

Labor:	
Plasterer, $2\frac{1}{4}$ days, at \$3.00 per day	\$6.75
Helper, $2\frac{1}{4}$ days, at \$1.50 per day	3.375
Cartage	1.00
Total	\$21.34

Cost per sq. yd., \$21.34 ÷ 100 = 21 cents, approximately.

Cost of Stucco Cornice per Square Foot.

Assumed cost per square foot	\$0.24

Summary.

From the preceding estimates of quantities and costs the following figures are obtained:

1,853 sq. yd. of 3-coat work, at 26 cents per sq. yd.	\$481.78
143.6 sq. yd. of 2-coat work, at 21 cents per sq. yd.	30.16
787 sq. ft. of stucco cornice, at 24 cents per sq. ft.	188.88
Total cost of plastering	\$700.82

JOINERY.

70. As there are so many different sizes in the joinery work, no attempt has been made to make detailed estimates of the cost of each; but the general method of obtaining the costs is that given in the preliminary articles on "Joinery."

DOOR FRAMES.

First Floor.

Chestnut frames—jambs $1\frac{1}{8}''$ rabbeted; casing $\frac{7}{8}'' \times 5\frac{1}{2}''$, with $\frac{1}{4}$-inch edge mold; back-band molding $\frac{7}{8}'' \times 2''$; plinth and corner blocks:

1 frame, 3′ 2″ × 7′ 9″ × 6″ (vestibule)	\$3.39
1 frame, 3′ 2″ × 7′ 9″ × 9″ (3-inch jamb), front door	4.14
1 frame, 5′ 6″ × 7′ 9″ × 14″ (sliding door)	3.86
1 frame, 4′ × 7′ 9″ × 14″	3.75
1 frame, 3′ × 7′ 9″ × 14″	3.62
2 frames, 2′ 8″ × 7′ 9″ × 6″, \$3.33 each	6.66
2 frames, 22″ × 7′ 9″ × 4″, \$2.32 each	4.64

White pine—jambs 6″×1⅛″ rabbeted; casings ⅞″×5″; back-band molding 2″×⅞″; plinth and corner blocks:

4 frames, 2′ 8″×7′ 9″, $3.33 each	$13.32
2 frames, 2′ 6″×7′ 9″, $3.24 each	6.48
1 frame, 2′ 10″×7′ 9″	3.38
Total	$53.24

Second Floor.

White pine, similar to first floor:

8 frames, 2′ 8″×7′ 6″, $3.28 each	$26.24
6 frames, 2′ 6″×7′ 6″, $2.98 each	17.88
1 frame, 2′ 2″×7′ 6″	2.72
1 frame, 2′ 4″×7′ 6″	2.80
1 frame, 2′ 6″×7′ 0″	2.70
Total	$52.34

Attic.

White pine, similar to second-floor doors:

6 frames, 2′ 8″×6′ 8″ at $2.72	$16.32
1 frame, 2′ 6″×6′ 6″	2.48
Total	$18.80

Summary.

First floor	$53.24
Second floor	52.34
Attic	18.80
Total cost of door frames	$124.38

DOORS.

The prices of doors do not include hardware or labor in hanging, both of which items will be found in the hardware bill.

First Story.

Solid chestnut, 6 and 7 raised panels, planted moldings:

1 pair sliding, 2′ 9″×7′ 9″×2″	$16.20
1 single sliding, 4′×7′ 9″×2″	14.13

1 single sliding, 3′×7′ 9″×2″....................	$9.26
1 lavatory, 2′ 4″×6′×1¾″ (frame included in paneling)................................	7.46
2 closet doors, 22″×7′ 9″×1¾″, solid molded, including glass in upper panel, at $5.60 each.......	11.20

Veneered Chestnut Doors.

1 front door, 3′ 2″×7′ 9″×2¼″, 3-panel, glass in top panel, price, including glass..................	$12.55
1 vestibule door, 3′ 2″×7′ 9″×2¼″, 3-panel, glass in top panel, price, including glass..............	12.55

Veneered Chestnut and Pine Doors.

1 in butler's pantry, 2′ 8″×7′ 9″×2″.............	$8.32
1 in butler's pantry, 2′ 8″×7′ 9″×1¾″...........	7.95

White-Pine Doors, Raised Panels.

2 glass doors, 2′ 4″×5′×1¼″, 1-panel, at $1.50 (china closet, no frames).........................	$3.00
4 doors, 2′ 8″×7′ 9″×1¾″, 5-panel, solid moldings, at $2.50 each................................	10.00
2 doors, 2′ 6″×7′ 9″×1¾″, 5-panel, solid moldings, at $2.30 each................................	4.60
1 door, 2′ 10″×7′ 9″×2″, 5-panel, solid molded....	3.00
2 outside cellar doors, at $1.00 each..............	2.00
Total..................................	$122.22

Second Floor.

1½-inch white pine, 5-panel, solid molded, raised panels:

8 doors, 2′ 8″×7′ 6″, at $2.30.....................	$18.40
6 doors, 2′ 6″×7′ 6″, at $2.15.....................	12.90
1 door, 2′ 6″×3′ 6″............................	1.00
1 door, 2′ 2″×7′ 6″............................	2.00
1 door, 2′ 4″×7′ 6″............................	2.10
2 wardrobe doors, 2′ 2″×6′×1¼″, including glass panels, at $1.50 each..........................	3.00
Total..................................	$39.40

Attic.

White pine, similar to second floor:

1 stuck-molded door, 2′ 6″ × 6′ 6″, glass panel	$2.76
6 doors, 2′ 8″ × 6′ 8″, at $2.00	12.00
Total	$14.76

Summary.

First story	$122.22
Second story	39.40
Attic	14.76
Total cost of doors	$176.38

WINDOW FRAMES.

Cellar.

No. 2 white pine, $1\frac{1}{2}'' \times 7''$ rabbeted jambs and head, and $2'' \times 7''$ sill. Complete, set in place:

1 window, 3 lights, 13″ × 10″	$1.09
2 windows, 1 light, 16″ × 10″, at $.79 each	1.58
4 windows, 2 lights, 14″ × 10″, at $.92 each	3.68
3 windows, 2 lights, 11″ × 10″, at $.82 each	2.46
2 windows, 2 lights, 13″ × 10″, at $.87 each	1.74
1 window, 3 lights, 11″ × 10″	1.03
Total	$11.58

First Story.

Frames in Brickwork.

Box frames, pulley stiles and hanging stiles $1\frac{1}{8}''$, sills 2″, and outer casing $\frac{7}{8}''$, all of No. 2 white pine. Inside casing with molded back band $5\frac{1}{2}'' \times \frac{7}{8}''$, stool $4'' \times 1\frac{1}{8}''$, apron $5'' \times \frac{7}{8}''$, sash stop $\frac{1}{2}'' \times 1\frac{1}{2}''$. Complete, set in place:

1 window, 2 lights, 40″ × 32″	$4.13
2 windows, 2 lights, 18″ × 32″, at $3.30 each	6.60
1 window, 2 lights, 24″ × 32″	3.60
1 window, 2 lights, 34″ × 32″	3.80
2 windows, 2 lights, 36″ × 32″, curved, at $7.80	15.60
	$33.73

Forward	$33.73
1 window, 2 lights, 30″×32″	3.90
1 window, 2 lights, 22″×24″	3.36
1 window, 4 lights, 31″×32″ (double)	6.80
2 windows, 3 lights, 15″×28″ (casement), at $4.00	8.00
Total	$55.79

Frames in Wooden Walls.

Pulley stiles $1\frac{1}{8}''$, sill 2″, subsills $1\frac{1}{8}''$, outside casings $\frac{7}{8}''$, inside casing with molded back band $5\frac{1}{2}''\times\frac{7}{8}''$, stool $4''\times 1\frac{1}{8}''$, apron $5''\times\frac{7}{8}''$, sash stop $\frac{1}{2}''\times 1\frac{1}{2}''$, all of white pine. Complete, set in place:

1 window, single light, 14″×28″	$3.00
3 windows, 2 lights, 26″×32″, at $3.44 each	10.32
1 window, 2 lights, 22″×32″	3.24
Total	$16.56

Second Story.

1 window, single light, 14″×28″	$3.00
2 windows, single light, 44″×28″, at $4.35 each	8.70
2 windows, single light, 23″×28″, at $3.30 each	6.60
3 windows, single light, 28″×28″, at $3.47 each	10.41
2 windows, single light, 36″×28″ (curved), at $7.36 each	14.72
3 windows, single light, 26″×28″, at $3.29 each	9.87
1 window, single light, 20″×28″	3.37
4 windows, single light, 30″×38″, at $3.67 each	14.68
Total	$71.35

Attic.

2 windows, single light, 18″×18″, at $3.06 each	$6.12
1 window (circular), 24″ diameter	3.00
2 double windows, two lights, 22″×24″ (curved), at $6.48 each	12.96
1 double window, 2 lights, 21″×24″	3.20
1 double window, 2 lights, 28″×20″	6.60
1 double window, 2 lights, 24″×20″	6.30
1 window, 2 lights, 28″×20″	3.25
1 window, 2 lights, 30″×28″	3.67
Total	$45.10

Summary.

Cellar	$11.58
First story in brick walls	55.79
First story in frame	16.56
Second story	71.35
Attic	45.10
Total cost of window frames	$200.38

WINDOW SASH.

Cellar.

1¼-inch white pine, glazed (price does not include hardware):

1 sash, 3 lights, 13″×10″	$0.64
2 sashes, 1 light, 16″×10″, at $.27 each	.54
4 sashes, 2 lights, 14″×10″, at $.36 each	1.44
3 sashes, 2 lights, 11″×10″, at $.33 each	.99
2 sashes, 2 lights, 13″×10″, at $.31 each	.62
1 sash, 3 lights, 11″×10″	.50
Total	$4.73

First Story.

Chestnut, 1¾-inch, prices including glazing, hanging sash, and putting on stops:

1 pair, single light, 40″×32″	$5.66
2 pairs, single light, 18″×32″, at $2.50 per pair	5.00
1 pair, single light, 24″×32″	2.75
1 pair, single light, 34″×32″	3.51
2 pairs, single light, 36″×32″ (curved), at $9.00 per pair	18.00
2 pairs, single light, 31″×32″ (double), at $4.02 per pair	8.04
1 pair, single light, 30″×32″	4.02
1 pair, single light, 22″×24″	2.62
2 pairs, 3 lights, 15″×28″ (casement), at $4.37	8.74
Pine:	
1 sash, 1 light, 14″×28″	1.25
3 pairs, 2 lights, 26″×32″, at $3.58 per pair	10.74
1 pair, 2 lights, 22″×32″	2.96
Total	$73.29

Pine:

Second Story.

1 sash, 1 light, 14″×28″	$1.25
2 sashes, 2 lights, 44″×28″, at $5.00 per pair	10.00
2 sashes, 1 light, 23″×28″, at $2.75 per pair	5.50
3 sashes, 1 light, 28″×28″, at $3.31 per pair	9.93
2 sashes, 1 light, 36″×28″ (curved), at $8.42	16.84
3 sashes, 1 light, 26″×28″, at $3.17 per pair	9.51
1 sash, 1 light, 20″×28″	2.50
4 sashes, 1 light, 30″×28″, at $3.54	14.16
Total	$69.69

Attic.

2 pairs, 2 lights, 18″×18″, at $1.80	$3.60
1 pair, circular, 24″ diameter	2.60
4 pairs, 2 lights, 22″×24″ (curved), at $4.22	16.88
2 pairs, 2 lights, 21″×24″, at $2.10	4.20
3 pairs, 2 lights, 28″×20″, at $2.50	7.50
2 pairs, 2 lights, 24″×20″, at $2.12	4.24
1 pair, 2 lights, 30″×28″	2.50
Total	$41.52

Screen Frames for Porch.

Rails and stiles, white pine, 4″×1½″, two muntins each:

1 frame, 36″×16″	$0.30
1 frame, 90″×16″	1.00
1 frame, 88″×16″	.95
1 frame, 60″×16″	.60
2 frames, 94″×16″, at $1.10 each	2.20
2 frames, 66″×16″, at $.65 each	1.30
1 frame, 24″×16″	.25
1 frame, 84″×16″	.90
1 frame, 20″×16″	.20
Total	$7.70

Summary.

Cellar	$4.73
First story	73.29
Second story	69.69
Attic	41.52
Screens	7.70
Total cost of window sash	$196.93

STAIRS.

Cellar Stairs.

52 ft. of hemlock, at \$.014 per ft.	\$0.73
46 ft. of planed white pine, at \$.03 per ft.	1.38
Labor: 12 risers, at \$.20 each.	2.40
Total	\$4.51

Back Stairs.

72 ft. planed white pine, at \$.03 per ft.	\$2.16
White-pine hand rails, 18 ft., at \$.10 per ft.	1.80
Labor: 13 risers, at \$.25 each.	3.25
Total	\$7.21

Main Stairs.

335 ft. of hemlock, at \$.014 per ft.	\$4.69
185 ft. of chestnut, at \$.045 per ft.	8.33
49 ft. of chestnut hand rail, at \$.50 per ft.	24.50
86 turned chestnut balusters, 2″×2″×10″, at \$.10 each	8.60
1 box newel, 8″×8″×4′ 6″, chestnut, paneled, with molded cap.	8.00
7 newels, 5″×5″×4′ 6″, chestnut, with turned pendants, at \$4.00	28.00
2 newels, 5″×5″×12′, chestnut, with turned caps, at \$8.00	16.00
Spandrel, 30 sq. ft., 10 raised panels, ⅞-inch thick stiles and rails, 1¼-inch thick planted molding, at \$.18 per sq. ft.	5.40
Paneled partition under stairs, chestnut, 17 sq. ft., at \$.18 per sq. ft.	3.06
String molding, 46′ of 1½″×3″, chestnut, at \$.09	4.14
Skirt molding, 46′ of 1½″×¾″, chestnut, \$.02	.92
Soffit molding, 38′ of ⅝″×2″, chestnut, \$.025	.95
Labor: 35 risers, at \$1.15 each.	40.25
Total	\$152.84

Summary.

Cellar stairs	$4.51
Back stairs	7.21
Main stairs	152.84
Total cost of stairs	$164.56

MISCELLANEOUS INTERIOR JOINERY.

Baseboard.

First story:	
Chestnut, $\frac{7}{8}'' \times 6''$, with molding worked on face, tongued into surbase, $1\frac{1}{8}'' \times 6''$, 139 ft., at $.26 per lin. ft.	$36.14
White pine, $\frac{7}{8}'' \times 9''$, plain, 90 ft., at $.055	4.95
Second story:	
White pine, $\frac{7}{8}'' \times 9''$, molded, 300 ft., at $.09 per lin. ft.	27.00
Attic:	
White pine, $\frac{7}{8}'' \times 6''$, molded, 290 ft., at $.03	8.70
Total	$76.79

Wainscoting.

First story:	
White pine, $\frac{7}{8}'' \times 2\frac{1}{2}''$, beaded and matched boards, 4 ft. high, 132 sq. ft., at $.065 per sq. ft.	$8.58
Molded cap, $1\frac{1}{2}'' \times 1\frac{1}{2}''$, 65 ft., at $.02\frac{1}{4}$ per ft.	1.46
Chestnut, paneled, $67' \times 4'$ high = 268 sq. ft., at $.18 per sq. ft.	48.24
Molded cap, $1\frac{1}{4}'' \times 4''$, 67 ft., at $.10 per ft.	6.70
Second story (bathroom):	
White pine, $\frac{7}{8}'' \times 2\frac{1}{2}''$, matched boards, 4 ft. high, 128 sq. ft., at $.065 per sq. ft.	8.32
Total	$73.30

Picture Molding.

Chestnut, $3'' \times 1\frac{1}{2}''$, 231 ft., at $.09	$20.79

China Closet.

No. 1 white pine, dressed, 97 ft. B. M., at $.03 per ft.	$2.91
Crown molding, $1\frac{1}{2}'' \times 3''$, 8 ft., at $.045 per ft	.36
Labor: 1 man, 2 days, at $2.25	4.50
Total	$7.77

Shelving.

No. 1 white pine, 50 ft. B. M., at $.03 per ft.	$1.50
Labor: 1 man, 1 day, at $2.25	2.25
Total	$3.75

Summary.

Baseboard	$76.79
Wainscoting	73.30
Picture molding	20.79
China closet	7.77
Shelving	3.75
Total cost of miscellaneous items	$182.40

MISCELLANEOUS EXTERIOR WORK.

Moldings.

356 ft. crown molding, $1\frac{1}{8}'' \times 4''$, at $.05	$17.80
356 ft. bed molding, $1'' \times 3''$, at $.03	10.68
356 ft. bed molding, $1'' \times 1\frac{1}{2}''$, at $.01½	5.34
74 ft. bed molding, $1'' \times 2''$, at $.02	1.48
356 ft. bed molding, $\frac{1}{2}'' \times \frac{7}{8}''$, at $.01	3.56
64 ft. neck molding, at $.01	.64
36 ft. cove molding, $\frac{7}{8}'' \times 1\frac{1}{8}''$, at $.01¼	.45

Miscellaneous.

White pine:

35 ft. triglyphs, at $.10	$3.50
207 turned balusters, $2'' \times 1' 6''$, for porches, at $.10.	20.70
92 ft. molded hand rail, $5'' \times 3''$, at $.30	27.60
92 ft. bottom rail, $5'' \times 3''$, at $.15	13.80
200 dentils, $2'' \times 2'' \times 3''$, at $.01	2.00
432 ft. B. M., outside window casing, at $.03	12.96
137 ft. window cap, $3'' \times 1\frac{1}{2}''$, at $.02	2.74
23 ft. B. M., for balustrade posts, at $.03	.69
Casing for circular window	1.00
Semicircular head casing over outside door in dormer	1.50
Total cost of exterior work	$126.44

RECAPITULATION OF COST OF JOINERY.

Door frames	$124.38
Doors	176.38
Window frames	200.38
Window sash	196.93
Stairs	164.56
Miscellaneous interior joinery	182.40
Miscellaneous exterior work	126.44
Total cost of joinery	$1,171.47

HARDWARE.

71. The prices given in the following list are based on the use of the best quality of hardware in the market. Should inferior quality be used, these prices would probably be 50 per cent. less. The cost of labor is assumed to be one-fifth the cost of the hardware.

Quantities and Cost.

Locks.

One 5⅜-inch mortise front-door lock, with bronze furniture complete	$7.50
One 4½-inch mortise vestibule-door lock, with bronze furniture complete	7.00
One 5½-inch flush pull mortise lock for double sliding door	3.50
Two 5½-inch flush pull mortise locks for single sliding door, with bronze furniture complete	5.50
Eighteen 4½-inch mortise knob locks, at $2.20	39.60
Ten 4-inch duplex flush cupboard locks, at $1.85	18.50
Six 2⅜-inch mortise knob locks, at $1.60	9.60
One 2-inch steel spring padlock	.60
Labor, 20 per cent. of cost of locks	18.36
Total	$110.16

Hinges.

One pair of double-acting checking spring hinges with bronze push plates, for double-acting door	$10.50
2 pairs 5″×5″ bronze loose pin butts, at $1.95.....	3.90
33 pairs 4″×4″ bronze loose pin butts, at $1.40....	46.20
2 pairs 3″×3″ bronze loose pin butts, at $.90......	1.80
Labor, 20 per cent. of cost of butts...............	12.48
Total..................................	$74.88

Miscellaneous.

Thirty-two 1⅛″×2⅝″ bronze self-locking sash fasts, at $.80..................................	$25.60
Five 2″×2¼″ bronze cupboard turns, at $.40.......	2.00
Four 6″×1¼″ bronze flush bolts, at $1.50..........	6.00
Three doz. 5-inch japanned-iron coat hooks, at $.50.	1.50
1,200 lb. of lead sash weights, at $.07............	84.00
1 galvanized-iron hasp and staple.................	.20
1 McCabe patent door hanger, double.............	4.35
2 McCabe patent door hangers, single, at $2.70....	5.40
6 hanks of solid braided sash cord, 13½ lb., at $.20. per lb	2.70
Four 2¼-inch bronze draw pulls, at $.10	.40
Labor, 20 per cent. of cost	26.43
Total..................................	$158.58

Summary.

Locks	$110.16
Butts..	74.88
Miscellaneous................................	158.58
Total cost of hardware	$343.62

HEATING AND VENTILATING SYSTEM.

72. In taking off quantities for the heating and ventilating contract, attention should be given to the fact that the furnace and pipes, registers and borders, and the fireplace furniture are usually supplied by three different manufacturers.

Quantities and Cost.

Furnace.

One 53-inch cast-iron portable furnace set up in place	$125.00

Warm-Air and Smoke Pipes.

12 ft. of 4″×8″ tin W. A. pipe, at $0.11	$1.32
12 ft. of 3″×12″ tin W. A. pipe, at $0.12	1.44
13 ft. of 4″×10″ tin W. A. pipe, at $0.12	1.56
61 ft. of 10″ round tin W. A. pipe, at $0.12	7.32
12½ ft. of 8″ round tin W. A. pipe, at $0.10	1.25
4 ft. of 8″ galvanized-iron smoke pipe, at $0.15	.60
17 ft. of 10″ round fireclay flue lining, at $0.25	4.25
2½ ft. of 8″ round fireclay flue lining, at $0.20	.50
Labor, one-third of cost of materials	6.08
Total	$24.32

Registers.

Three 14″×16″ japanned floor registers, at $2.37	$7.11
One 7″×10″ japanned floor register	.57
One 12″×15″ japanned floor register	1.50
Two 7″×9″ japanned floor registers, at $0.57	1.14
One 10″×12″ japanned floor register	.84
Two 12″×15″ japanned wall registers, at $1.50	3.00
One 10″×12″ japanned wall register	.84
Labor, one-third of cost of materials	5.00
Total	$20.00

Tin Register Boxes.

Three 14″×16″×4″, at $0.80	$2.40
One 7″×10″×4″, at	.57
Two 10″×12″×4″, at $0.75	1.50
Two 15″×12″×4″, at $0.75	1.50
Two 7″×9″×4″, at $0.57	1.14
Labor, one-third of cost of materials	2.37
Total	$9.48

Soapstone Borders.

Three for 14″×16″ registers, at $2.22	$6.66
One for 7″×10″ register	.66
One for 12″×15″ register	1.47
Two for 7″×9″ registers, at $0.66	1.32
One for 10″×12″ register	1.02
Labor, one-third of cost of materials	3.71
Total	$14.84

Miscellaneous.

15 elbows, 10 inches in diameter, at $0.25	$3.75
2 elbows, 8 inches in diameter, at $0.20	.40
10 sheets of "IC" tin, 20″×28″, at $0.10	1.00
2 cold-air boxes, each 24 ft. long, of 20-inch earthen pipe, with two slide dampers and screens, at $0.80 per foot of pipe	38.40
Labor, one-third of cost of materials	14.52
Total	$58.07

Summary.

Furnace	$125.00
Warm-air and smoke pipes	24.32
Registers	20.00
Register boxes	9.48
Soapstone borders	14.84
Miscellaneous	58.07
Total cost of heating and ventilating system	$251.71

PLUMBING AND GAS-FITTING.

73. A complete list of the plumbing fixtures, together with the sizes, lengths, and materials of all pipes, should be tabulated so as to be easy of reference in case of alteration in the schedule.

PLUMBING.

Quantities and Cost.

Fixtures.

1 double-oven brick-set kitchen range with water-back; to be selected by the owner; complete...	$50.00
1 Class A, brown-glazed earthenware sink, 30″ × 20″ × 7″; with countersunk slate slab and back 18 inches high, front and side aprons 7 inches deep. Polished brass legs for slab and sink; apron holders, 2-inch cast brass, polished; S trap with waste pipe to floor; and polished improved "Fuller" faucets; complete...	65.00
1 Class A, porcelain recess pantry sink, white enameled inside, with nickel-plated standing waste overflow; with nickel-plated 1½-inch brass trap and pipe to floor; nickel-plated supply pipes to floor; nickel-plated 2-inch supporting stand, and heavy nickel-plated "Fuller" faucets, marked *hot* and *cold*; complete.......	50.00
1 six-foot porcelain-lined, roll rim, Roman pattern, cast-iron bath, with cast-iron feet, painted one coat outside, with nickel-plated combination standing waste, compression star handle supply valves at foot, with *hot* and *cold* name plates; complete	68.00
1 improved porcelain siphon-jet water closet, with quartered-oak seat and cover, quartered-oak siphon cistern, with nickel-plated brass brackets, nickel-plated brass flush pipe; nickel-plated chain and china pull, and brass floor flange; complete..................................	56.00
1 left-hand corner open lavatory, Italian marble slab, 33″ × 24″, with 16-inch back and end; 5-inch aprons, nickel-plated recess legs; oval basin, 19″ × 15″, ivory tinted; nickel-plated combination supply; "Fuller" faucets; standing waste and trap; nickel-plated pipes to floor; nickel-plated apron holders; china handles to faucets marked *hot* and *cold;* complete........	58.00
	$347.00

Forward	$347.00
1 Italian marble corner lavatory slab 22″×22″, with 12-inch backs; 2 nickel-plated brackets, one 14-inch round basin with hot and cold "Fuller" bibbs; combination standing waste; 1½-inch trap to wall; complete	38.00
1 set of 3 Class A, brown-glazed earthenware wash tubs, 30 inches long, 25 inches wide, and 14 inches deep; with 1½-inch lead waste pipe and 2-inch trap; nickel-plated waste plugs and sockets, and nickel-plated "Fuller" pattern flange and thimble faucets for hot and cold; complete	48.00
Cost of fixtures	$433.00

Water Supply.

1 forty-gallon galvanized-iron boiler, stand, and couplings, complete	$15.00
Tapping and corporation-cock permits	5.00
1 curb box	2.00
10 ft. of 1-inch brass pipe and fittings	5.00
40 ft. of 1-inch AAA lead pipe	15.00
44 ft. of 1-inch galvanized-iron pipe	4.00
120 ft. of ¾-inch galvanized-iron pipe	7.00
80 ft. of ½-inch galvanized-iron pipe	4.00
30 pounds of fittings	5.00
1 one-inch stop and waste cock	1.50
8 three-quarter-inch stop and waste cocks	7.00
3 half-inch stop and waste cocks	2.50
Straps and hangers	1.00
2 garden hose bibbs	2.00
Cost of water-supply system	$76.00

Drainage.

213 ft. 4-in. extra heavy cast-iron asphalt-coated soil pipe	$65.00
20 ft. 3-in. extra heavy cast-iron asphalt-coated soil pipe	4.00
110 ft. 2-in. extra heavy cast-iron asphalt-coated soil pipe	17.00

80 ft. 4-inch extra heavy cast-iron asphalt-coated soil-pipe fittings	$24.00
4 ft. 3-inch extra heavy cast-iron asphalt-coated soil-pipe fittings	2.50
24 ft. 2-inch extra heavy cast-iron asphalt-coated soil-pipe fittings	7.50
90 ft. of 6-inch salt-glazed earthenware sewer pipe.	10.00
62 ft. of 5-inch salt-glazed earthenware sewer pipe.	6.00
140 ft. of 4-inch salt-glazed earthenware sewer pipe.	8.00
1 six-inch fitting	1.00
7 five-inch fittings	4.00
18 four-inch fittings	7.00
Portland cement	2.00
100 lb. of lead	5.00
Oakum	1.00
Wall hooks	1.00
1 four-inch running trap	2.00
4 four-inch ground brass ferrule cleanouts	2.00
3 cast-iron manhole covers	3.00
1 fresh-air inlet box	1.00
1 four-inch lead bend	1.50
1 four-inch brass ferrule	.20
10 ft. of 2-inch lead waste pipe	2.50
14 ft. of 1½-inch lead pipe	2.50
12 two-inch brass ferrules	1.50
2 two-inch lead traps	2.50
2 square feet of 6-pound sheet lead	.70
3 four-inch wire-basket strainers	.40
20 lb. of wiping solder	4.00
Total	$188.00

Labor.

Labor, assumed to be one-fourth cost of all materials = $697.80 × .25 =	$174.45

Summary.

Fixtures	$433.00
Water-supply system	76.00
Drainage	188.80
Labor	174.45
Total cost of plumbing	$872.25

GAS-FITTING.

Quantities and Cost.

Fixtures.

Cellar:	
2 brackets, 1 burner, each at \$.50	\$1.00
First floor:	
Parlor, 1 chandelier, 4 burners	30.00
2 brackets, double swing, 1 burner, each at \$5.00	10.00
Dining room, 1 chandelier, 4 burners	20.00
2 brackets, double swing, 1 burner, each at \$3.00	6.00
Hall, 1 chandelier, 4 burners	25.00
Library, 1 chandelier, 3 burners	20.00
2 brackets, double swing, 1 burner, each at \$3.00	6.00
Lavatory, 1 bracket, 1 burner, double swing	2 50
Kitchen, 1 center fixture, 2 burners	4.00
1 side light, single swing, 1 burner	1.00
Butler's pantry, 1 drop light, 2 burners	3.00
Pantry, 1 side light, single swing, 1 burner	1.00
Cellar stairs, 1-bracket light, 1 burner	.50
Second floor:	
Bedrooms, 11 double swing brackets, 1 burner, at \$4.00	44.00
Dressing room, 1 double swing, plain, 1 burner	2.00
Hall, 1 stiff bracket, 2 burners	6.00
Stair landing, 2 stiff brackets, 1 burner, each at \$3.00	6.00
Bathroom, 1 bracket, double swing, plain, 1 burner	2.00
Attic rooms, 5 stiff brackets, 1 burner, each at \$.75	3.75
Total	\$193.75

Pipe and Fittings.

54 ft. $1\frac{1}{2}$-inch pipe, at \$0.08	\$4.32
30 ft. $\frac{3}{4}$-inch pipe, at \$0.05	1.50
30 ft. $\frac{1}{2}$-inch pipe, at \$0.04	1.20
205 ft. $\frac{3}{8}$-inch pipe, at \$0.03	10.25
Fittings	4.00
Total	\$21.27

Labor.

Labor, assumed to be one-seventh the cost of materials (fixtures, pipes, etc.) = \$215.02 ÷ 7 = ... \$30.72

Summary of Cost of Gas-Fitting.

Fixtures	\$193.75
Pipe and fittings	21.27
Labor	30.72
Total cost of gas-fitting	\$245.74

RECAPITULATION OF COST OF PLUMBING AND GAS-FITTING.

Plumbing	\$872.25
Gas-fitting	245.74
Total cost of plumbing and gas-fitting	\$1,117.99

PAINTING.

74. In taking off quantities for painting, it is usual to estimate the cost by assuming a price per square yard for each class of work, instead of estimating the material and labor separately.

Quantities.

Exterior Work.

Three coats of pure linseed oil and white lead in four colors:

	Sq. Yd.
Shingles (see item in "Carpentry" estimate)	269
Main cornice	130
Porch cornice	23
Porch posts	32
Spandrels	40
Porch skirting	14
Balustrade	53
Sash	64
Window sills	16
Porch floors and steps	72
Total	**711**

	Sq. Yd.
One coat orange shellac and one of varnish:	
Porch ceiling (see item in "Carpentry" estimate)	58

Interior Work.

Chestnut finish, parlor, library, dining room, hall, stair hall, lavatory, and stairway. One coat of wood filler, one coat of white shellac, and two coats of varnish, rubbed down with pumice stone and water:

	Sq. Yd.
Architrave	32
Base	16
Wainscoting	30
Sash	17
Doors	54
Jamb casings	7
Stairway	50
Balustrade of stairway	20
Total	226

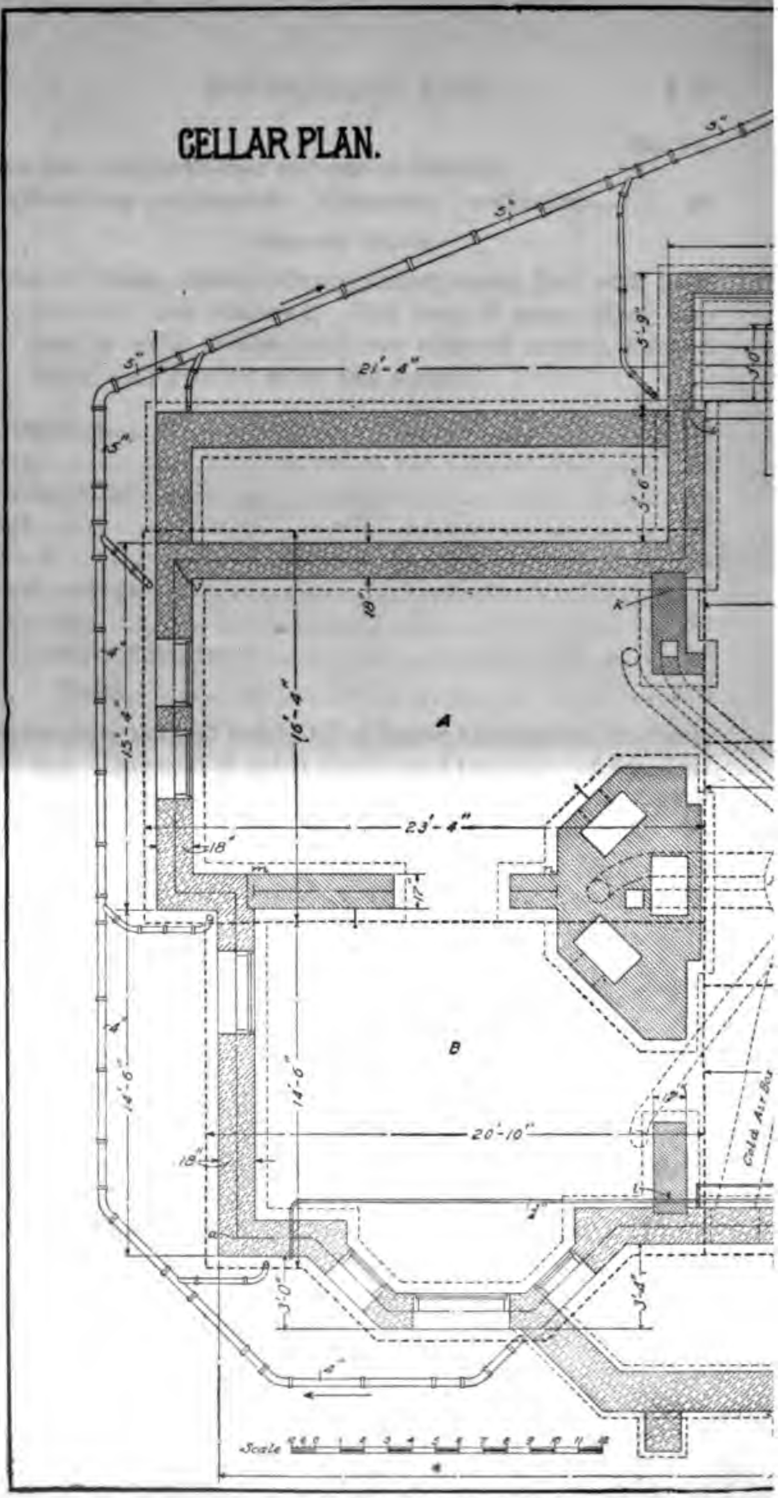
White pine, natural finish, all of house not finished in chestnut. One coat of spirit shellac and two coats of varnish:

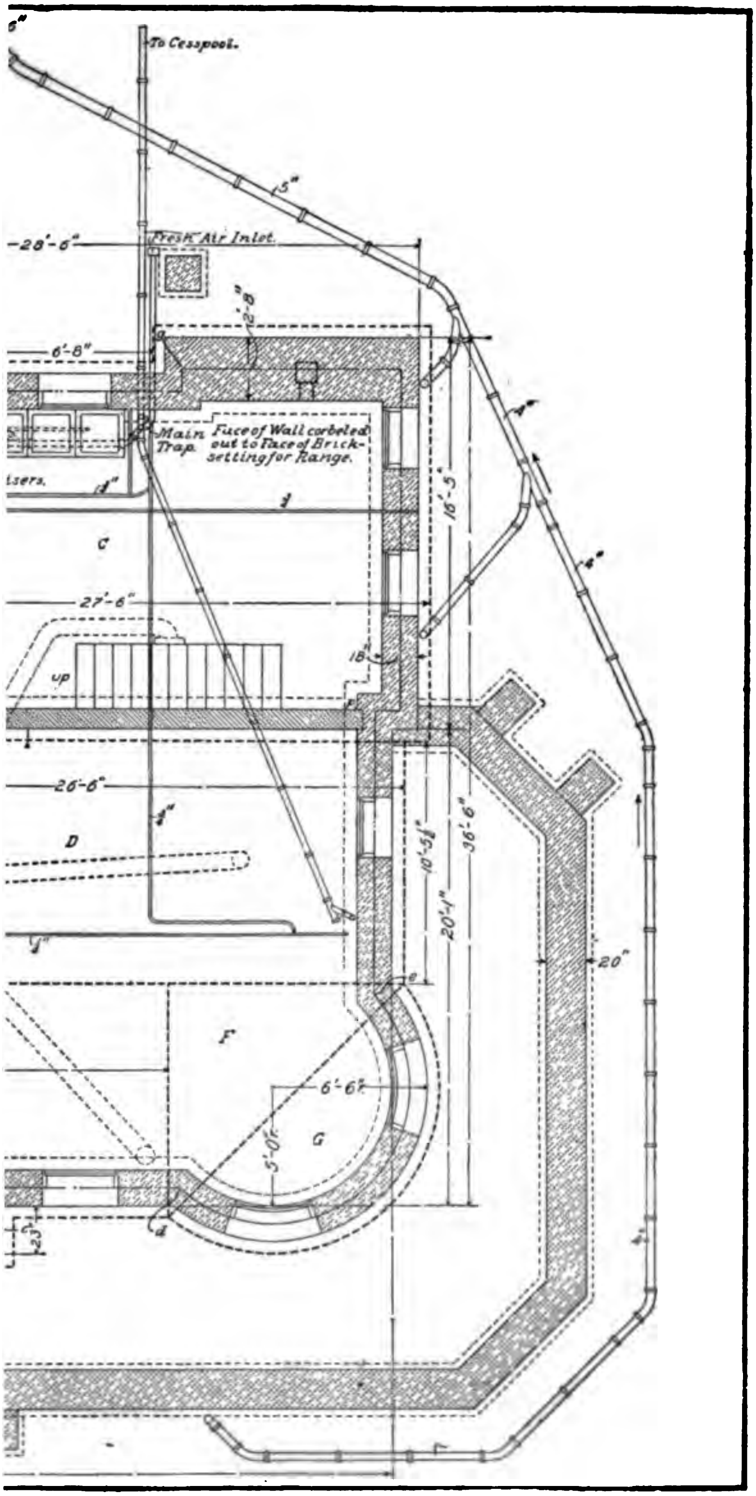
	Sq. Yd.
Architrave	73
Base	60
Wainscoting	29
Sash	40
Dresser	9
Doors	131
Jamb casings	31
Back stairs	34
Total	407

Cost.

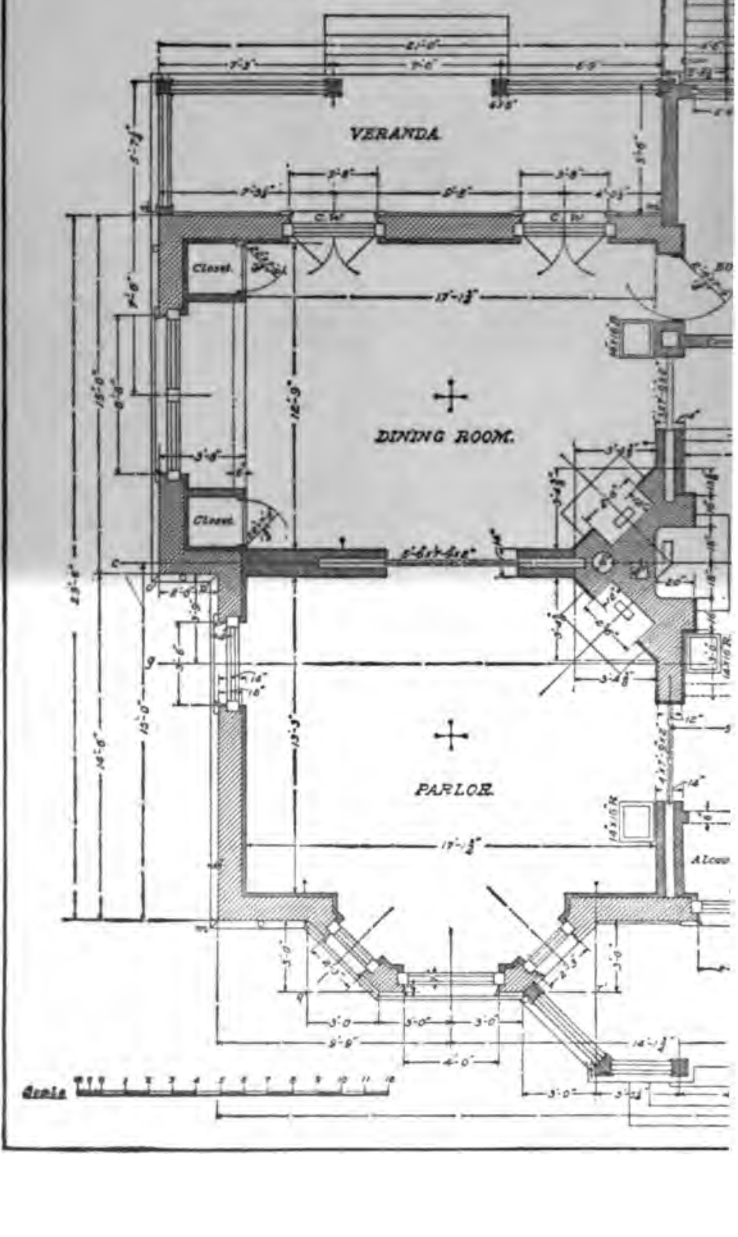
Exterior work, 711 sq. yd., at 28 cents per sq. yd.	$199.08
Porch ceiling, 58 sq. yd., at 20 cents per sq. yd.	11.60
Chestnut finish, 226 sq. yd., at 50 cents per sq. yd.	113.00
White pine, natural finish, 407 sq. yd., at 25 cents per sq. yd	101.75
Total cost of painting	$425.43

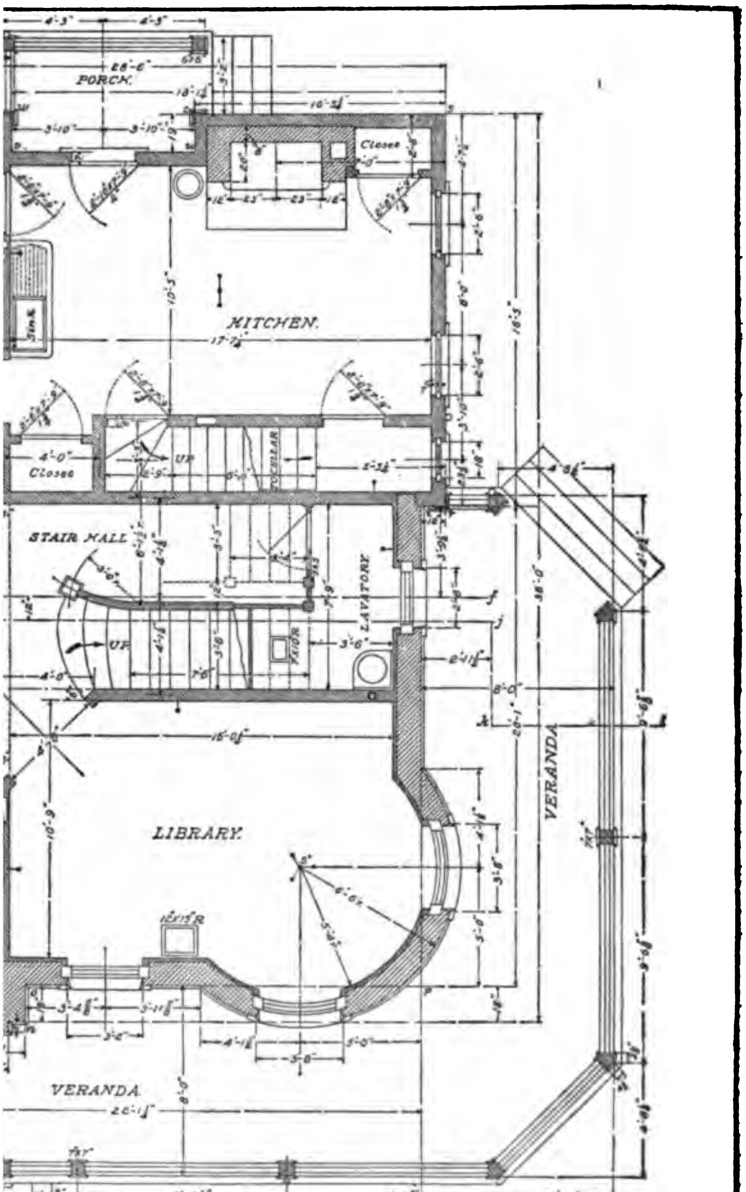
CELLAR PLAN.

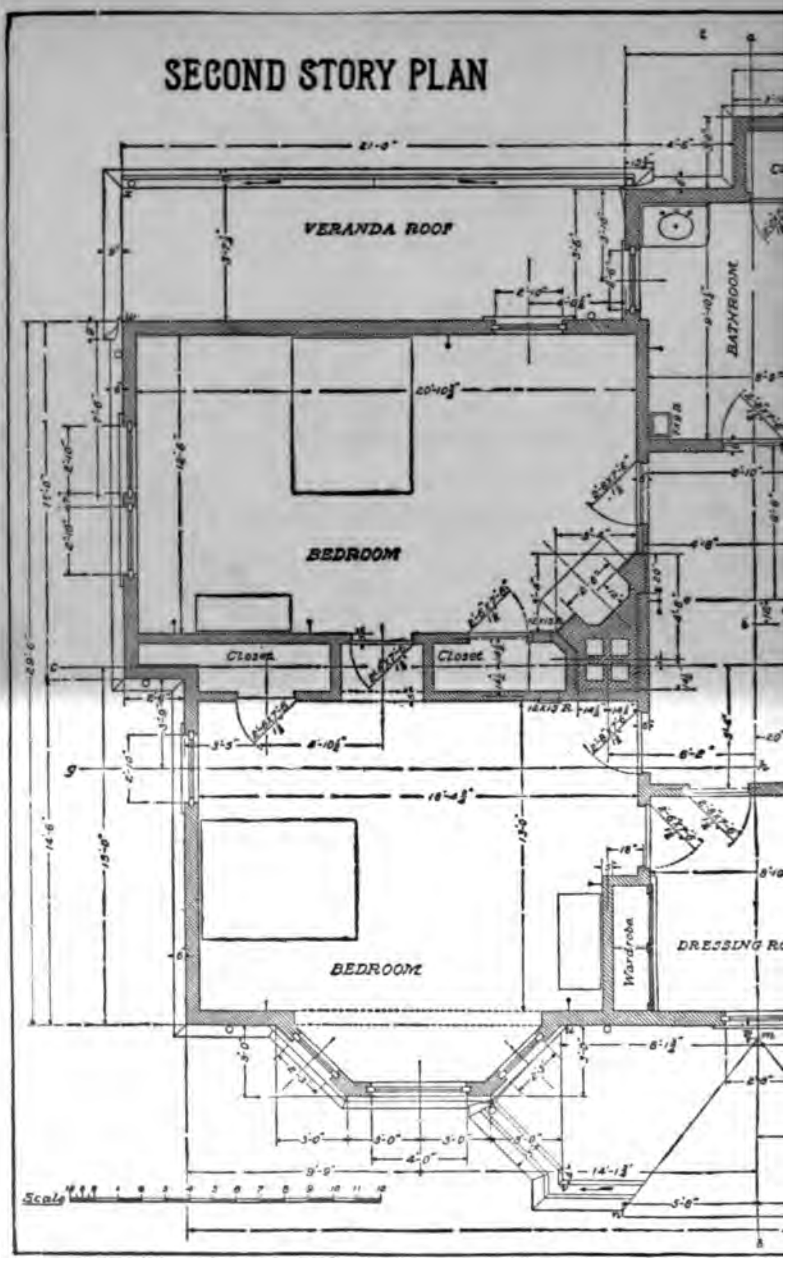

21'-4"
5'-9"
3'-0"
3'-6"
18"
16'-4"
13'-8"
A
23'-4"
18"
17"
B
14'-6"
14'-6"
20'-10"
18"
Cold Air Box
3'-0"
3'-4"
5"
4"

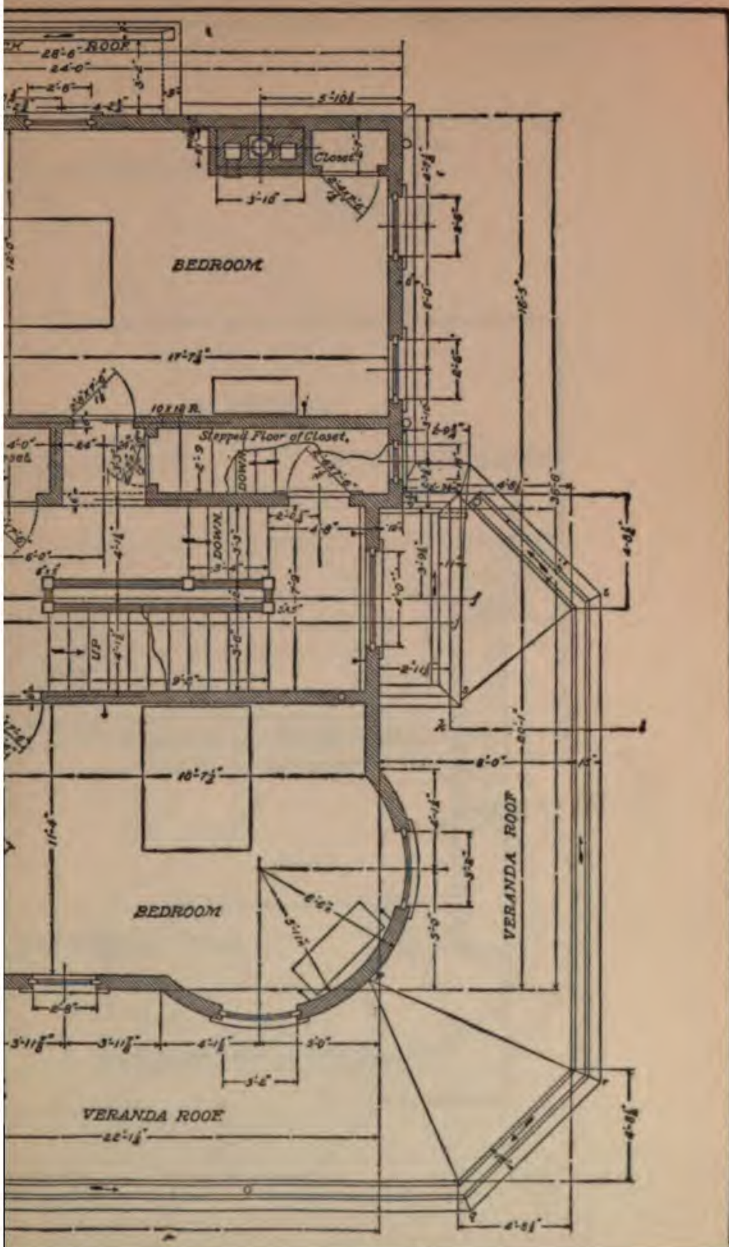

To Cesspool.
5"
28'-6"
Fresh Air Inlet.
2'-8"
6'-8"
Main Trap.
Face of Wall corbeled out to Face of Brick-setting for Range.
16'-5"
4"
C
27'-6"
18"
up
26'-6"
D
10'-5½"
36'-6"
20'-1"
20"
F
6'-6"
G
5'-0"
d
e

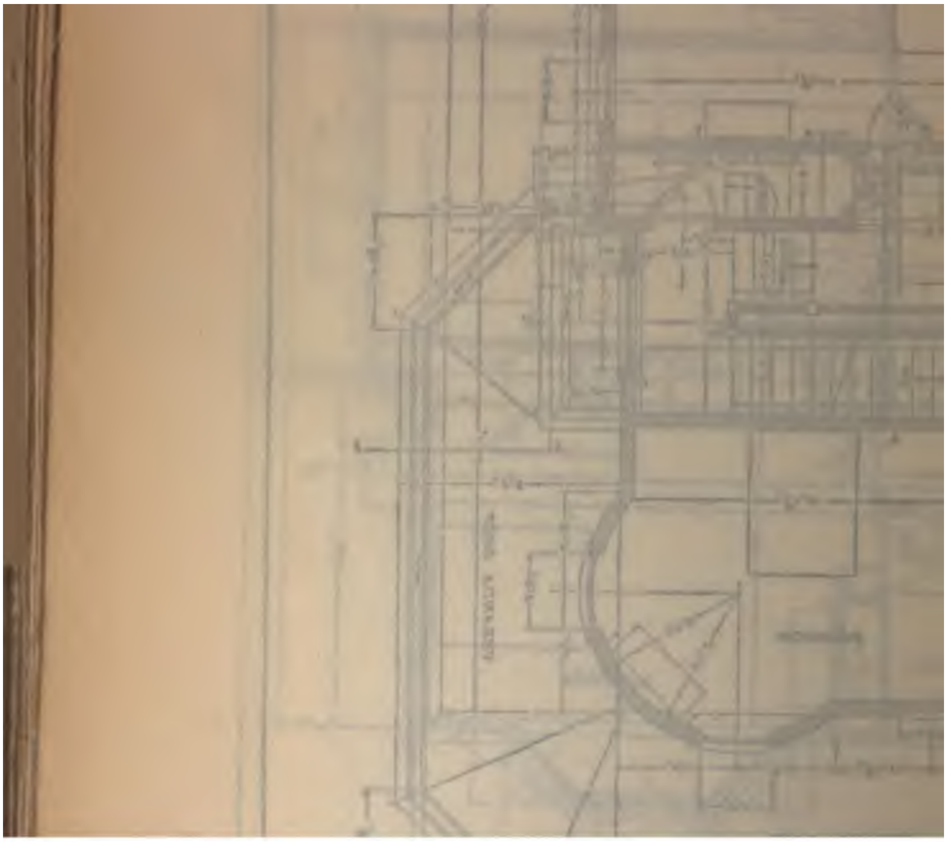
FIRST STORY PLAN.



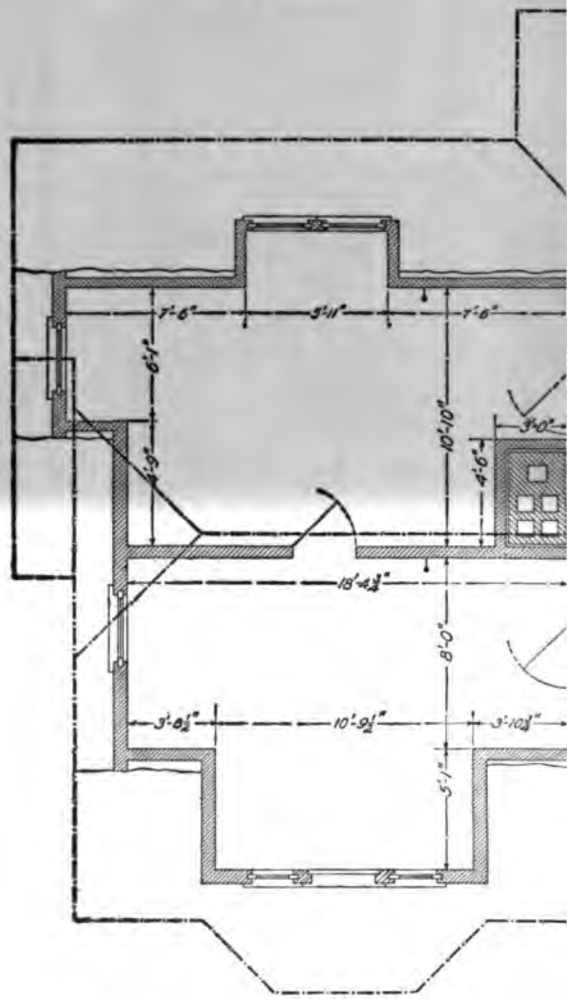

PORCH.
Closet
KITCHEN.
Sink
Closet
UP
STAIR HALL
UP
LAVATORY
LIBRARY.
VERANDA
VERANDA.

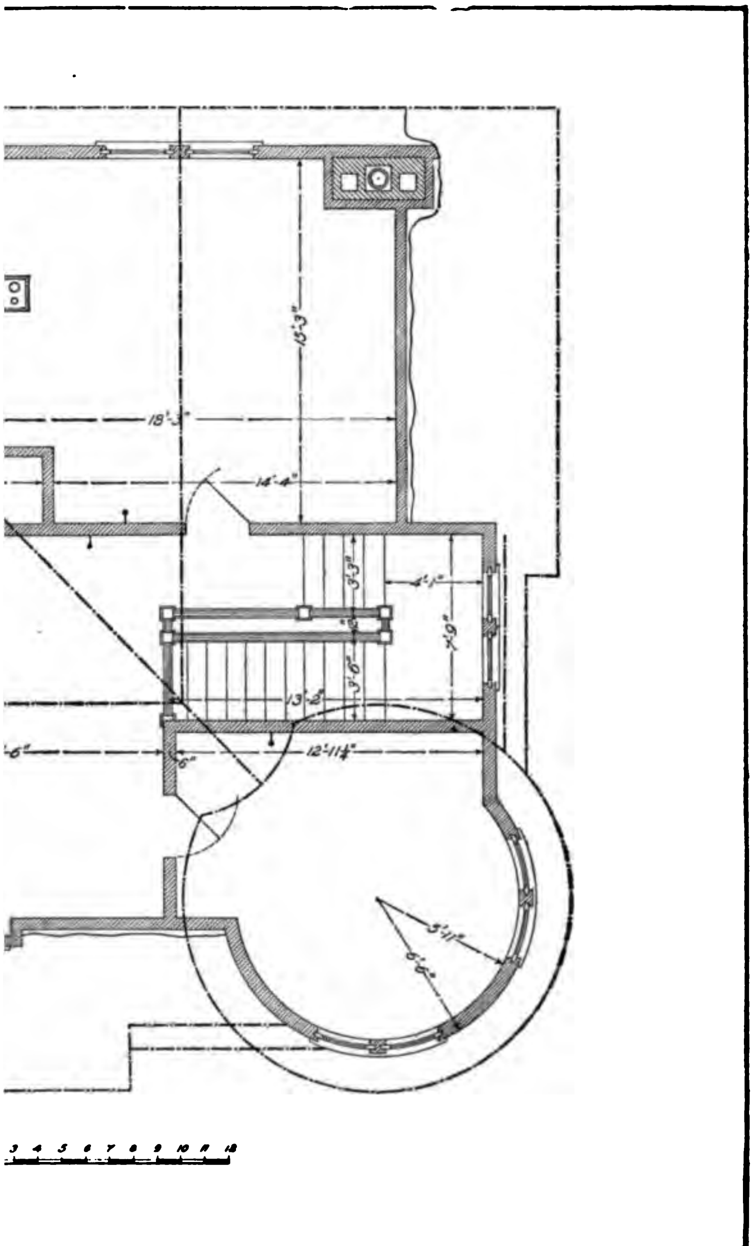

SECOND STORY PLAN
VERANDA ROOF
BEDROOM
Closet
Closet
BATHROOM
BEDROOM
Wardrobe
Scale

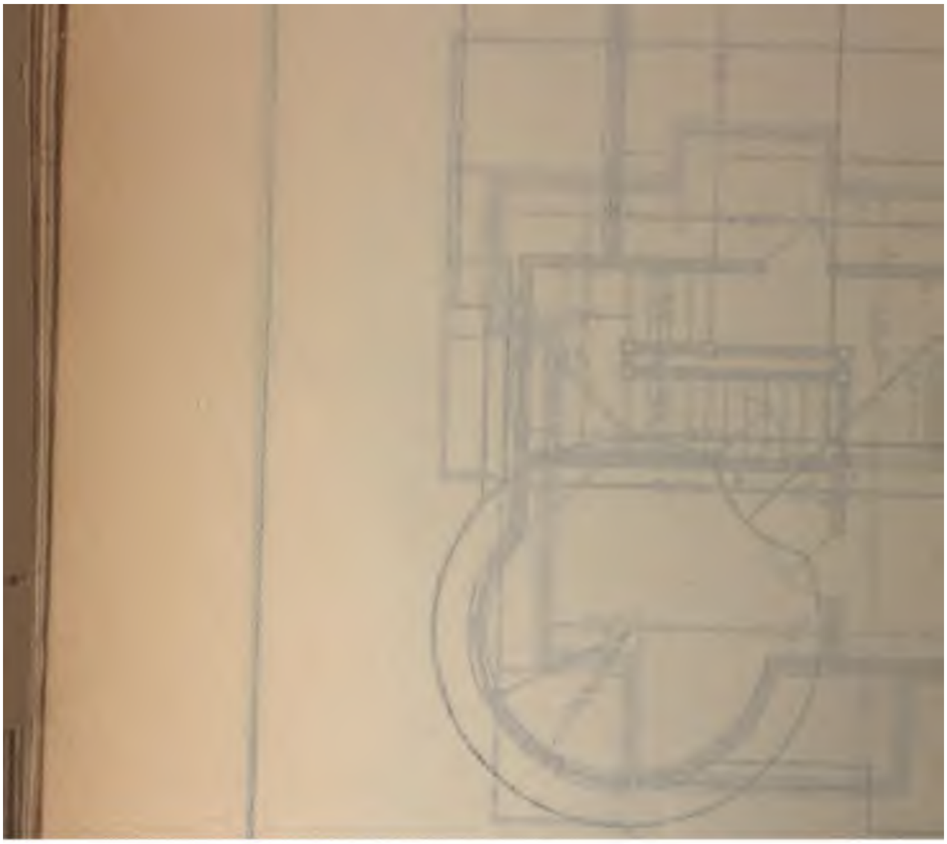

ROOF
Closet
BEDROOM
Stepped Floor of Closet.
DOWN
UP
BEDROOM
VERANDA ROOF
VERANDA ROOF



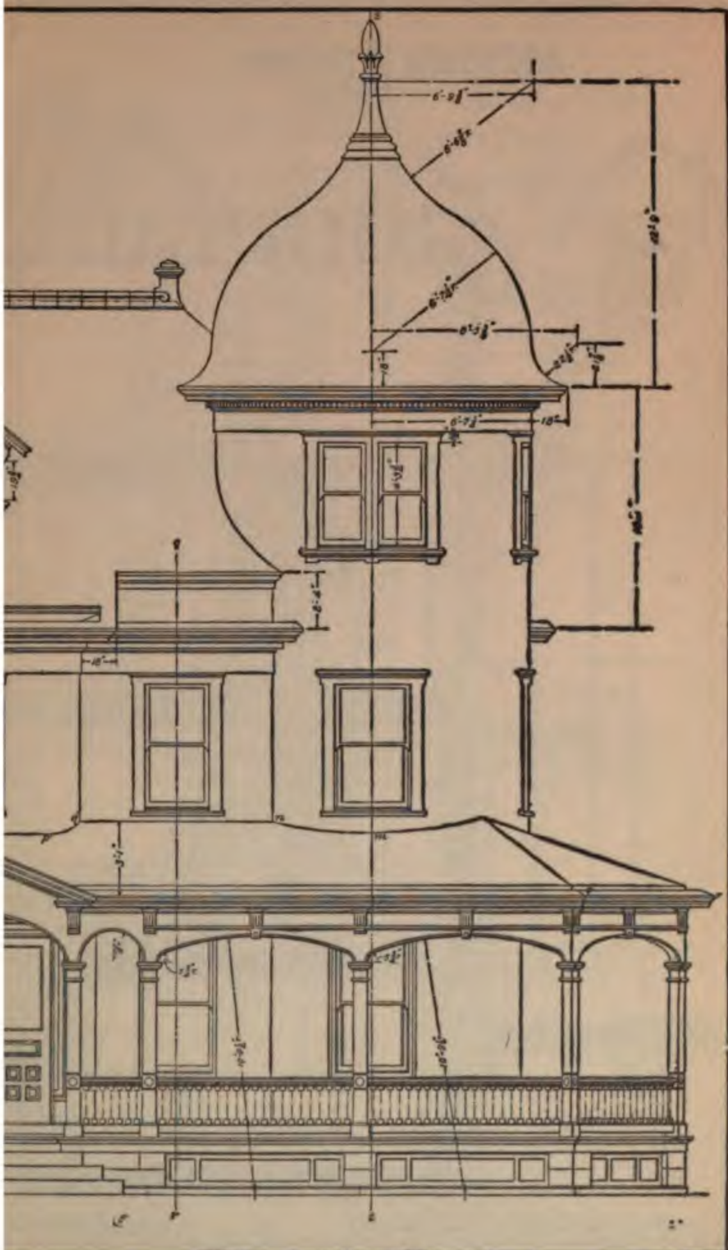
ATTIC PLAN.

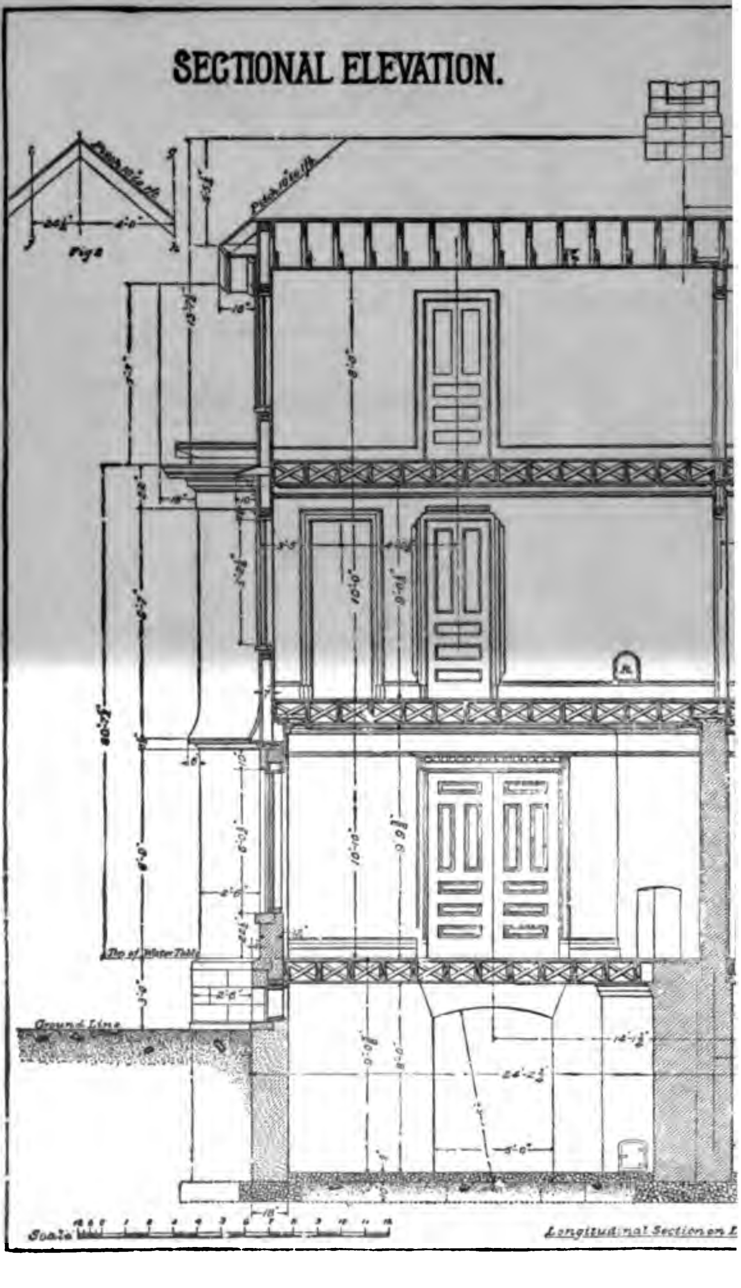


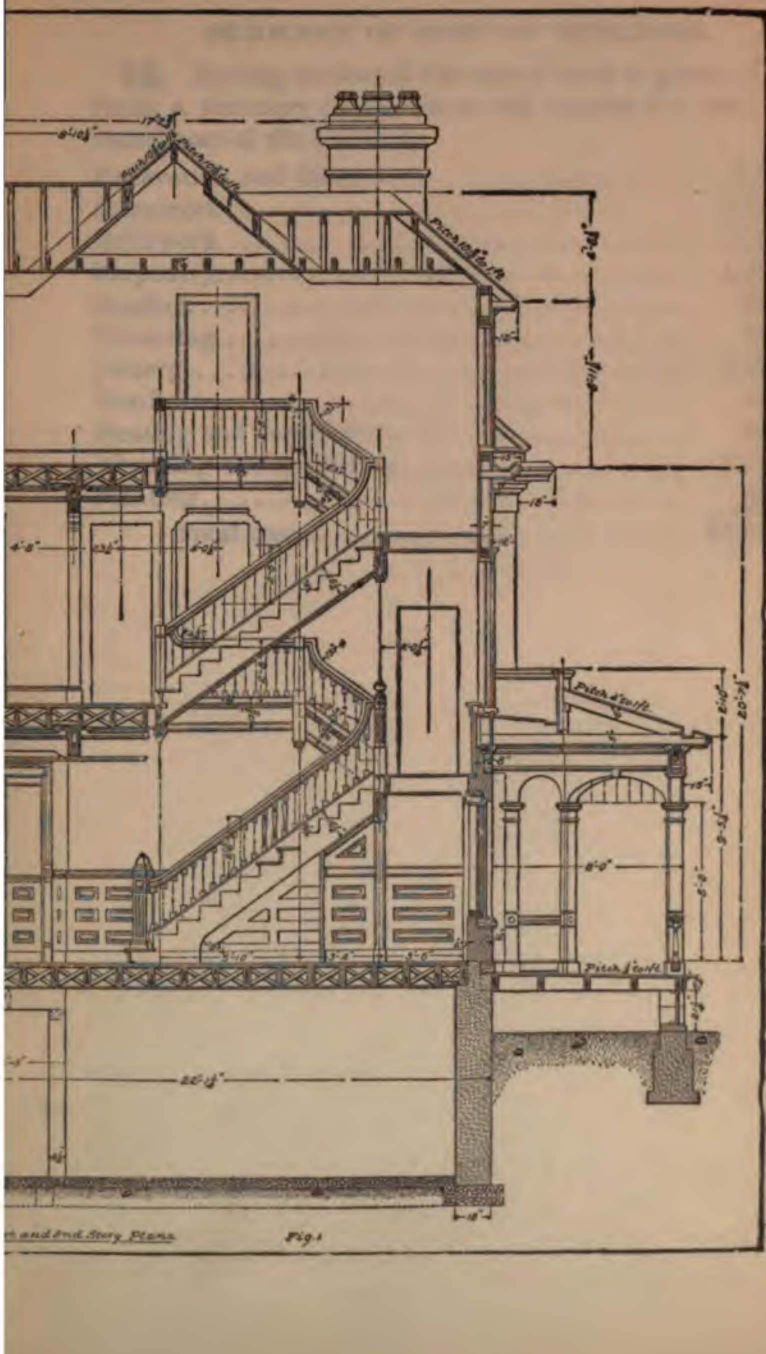

15'-3"
18'-3"
14'-4"
3'-3"
4'-1"
7'-9"
3'-6"
13'-2"
12'-11½"
5'-11"
6'-6"
3 4 5 6 7 8 9 10 11 12



FRONT ELEVATION
Fig. 1
Section Through A.B.
Scale




SECTIONAL ELEVATION.
Fig 8
Top of Water Table
Ground Line
Scale
Longitudinal Section on



n and 2nd Story Plans Fig. 1

SUMMARY OF COST OF BUILDING.

75. Having estimated the cost of work required of each trade, a summary of the whole will express the total estimated cost of the building.

Excavation and filling	$174.16
Stonework	1,314.41
Brickwork	791.71
Carpentry	1,023.10
Roofing	415.58
Plastering	700.82
Joinery	1,171.47
Hardware	343.62
Heating and ventilation	251.71
Plumbing and gas-fitting	1,117.99
Painting	425.43
Total cost	**$7,730.00**

INDEX.

NOTE.—All items in this index refer first to the section (see the Preface) and then to the page of the section. Thus, "Asphalt 18 23" means that asphalt will be found on page 23 of section 18.

H.

I.

J.